ROBERT REYNOLDS CROWELL, President,
1909.

THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK

PROCEEDINGS

FOR

1909

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PROCEEDINGS OF THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK

IN NON-CONTINUATION OF THE POLICY ADOPTED FOR THE PROCEEDINGS OF THE PREVIOUS TWO YEARS, THIS VOLUME HAS NOT BEEN PRINTED IN ACCORDANCE WITH THE RULES FOR SPELLING RECOMMENDED BY THE "SIMPLIFIED SPELLING BOARD," OF No. 1 MADISON AVENUE, NEW YORK CITY.

THE EDITOR HEREWITH EXPRESSES HIS REGRET THAT THE SPELLINGS FOUND IN THIS VOLUME HAVE BECOME NECESSARY, BUT BOWS TO THE WILL OF SUPREME AUTHORITY.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 46.

PRESENTED FEBRUARY 24TH, 1909.

AN ADDITIVE METHOD OF RUN-OFF DETERMINATION FOR STORM-WATER SEWERS.

BY CARL H. NORDELL,* M. M. E. N. Y.

WITH DISCUSSION BY
ROBERT CROWELL, ALBERTO SCHREINER, CHAS. E. GREGORY, A. PRESCOTT FOLWELL, VICTOR H. REICHELT, JOHN T. FETHERSTON, ARTHUR S. TUTTLE, GEO. L. CHRISTIAN, E. J. FORT AND CARL H. NORDELL.

Probably the first attempt to formulate a method of storm-water sewer design was made in 1849 by an English engineer, John Rowe, who compiled a set of tables showing the acreage supposed to be drained by various sizes of sewers laid to different grades. It was, naturally, extremely crude, no allowance being made for any of the varying factors of different drainage areas, such as rainfall, imperviousness, slope or manner of collection, all of which have a marked influence upon the necessary sizes of sewers.

These were, to a certain extent, remedied by formulæ so constructed as to take some of these variables into consideration. The first to come into general use was the Burkli-Ziegler, $Q = A\,C\,R\sqrt[4]{\frac{S}{A}}$, in which A is the acreage, R the maximum rate of rainfall in inches per hour, C a coefficient of imperviousness and S the average slope of the drainage area in feet per thousand. This formula has usually been found to give too small results and it was probably this that induced McMath to propose his modification of the expression from data obtained by gaging the flow of

* Bureau of Sewers, Borough of Queens, New York City.

sewers in St. Louis. The formulæ devised by Hering and Parmley give still greater results than McMath's. For the purpose of comparison they may all be written in the same form:

Berkli-Ziegler....	$Q = A^{.75}\ S^{.25}\ C\ R$
McMath.........	$Q = A^{.80}\ S^{.20}\ C\ R$
Parmley.........	$Q = A^{.833}\ S^{.25}\ C\ R$
Hering..........	$Q = A^{.85}\ S^{.27}\ C\ R$

It will be seen that the form has been kept exactly the same but the exponents of A and S changed to give greater results. Then, too, the tendency has been to increase R, McMath using a value of 2.75 and Parmley 4.00.

These formulæ are entirely emperical and can give correct results only for areas identical to those from which they were derived, because of the fact that some very important factors in determining run-off, the shape of the area, the manner of collection and the time of concentration are entirely left out of consideration. The value of S also affects the run-off differently in different portions of an area. For instance, a large value of S in the upper portion of an area and a small value of S in the lower portion tends to a large run-off, since the maximum amount of run-off from the upper end reaches the lower end of the area before the maximum amount in that portion has been discharged. Obviously, if the slopes are reversed the opposite conditions prevail even though the average slope of the whole territory remains the same.

The "Rational Method" of run-off determination, as developed by Emil Kuichling, overcomes some of these inaccuracies; the time of concentration is employed in determining the run-off; Q is taken equal to $A\ C\ R$, in which A is the acreage, C the coefficient of imperviousness and R the average rainfall for T minutes, T being the time taken by the water to flow from the furthermost point of the area to the point under consideration. This method does not, however, adapt itself exactly for varying slopes and manners of collection, for it will readily be seen that we may have any number of areas whose time of concentration from the furthermost point is the same and yet vary widely in shape and manner of collection.

When Parmley designed the Walworth Street sewer in Cleveland, which drained a triangular area, the line of the sewer being approxi-

PLATE 1.
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NORDELL ON RUN-OFF DETERMINATION
FOR STORM-WATER SEWERS.

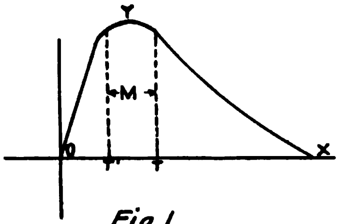

Fig. 1.

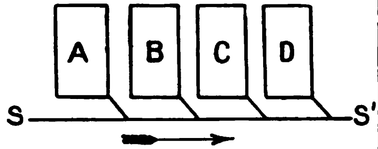

Fig. 2.

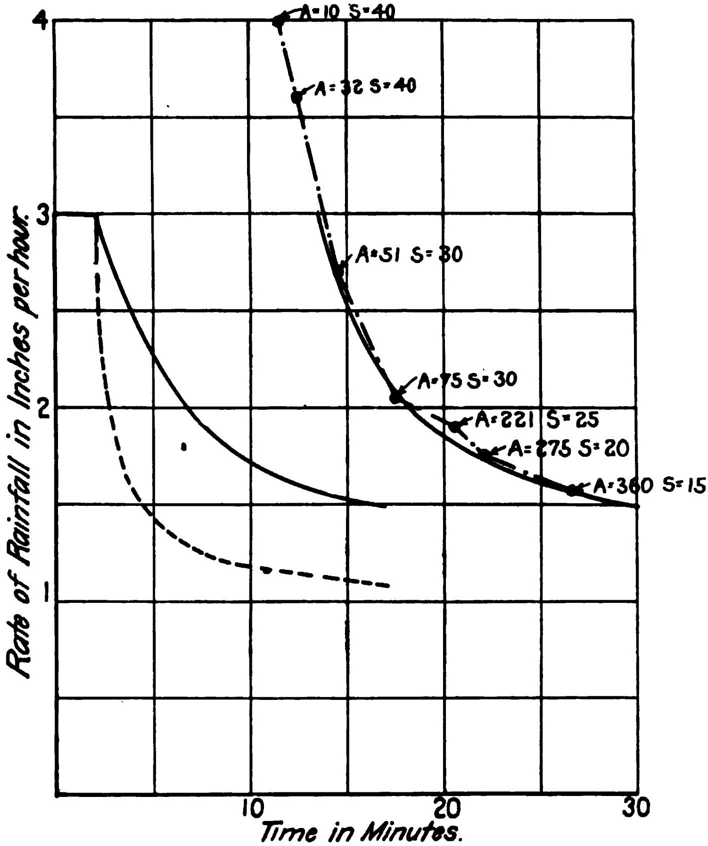

Fig. 3.

mately the median of the triangle, he found that the time of reaching any point in the main trunk was about the same for the limits of the area. Instead of applying a formula directly in order to determine the run-off to be carried by the main sewer, the run-off for the contributory trunks were determined by his formulæ and the discharge of the main trunk taken as their sum. This method was undoubtedly correct for that particular drainage district, but could not, of course, be used for any drainage district in which these peculiar conditions did not exist. None of these formulæ or methods can therefore be relied upon to give correct results for all areas, and considerable judgment must be used in applying them. As using an empirical formula with judgment involves much guesswork, it would seem better to outline a method correct in theory, and employ judgment in fitting practice to theory.

If, therefore, we begin an investigation of run-off from a surface such as an inclined plane, where the most simple conditions possible prevail, we will probably be able to build up a method of determining the run-off from any area made up of a number of such surfaces.

The rainfall is, of course, never constant for any considerable time and must therefore be at a maximum for some time during the continuation of the storm. This will be called in the following discussion the "maximum rate," and the greatest flow of storm water past a given point the "maximum flow." Suppose the plane to be included from the upper edge P' to the lower edge P, the length of time taken by the water to flow from P' to P will be called the "time length" of the area. The problem is to find the amount and time of occurrence of the maximum flow at P.

In Plate 1, Fig. 1, let the line $O\ Y\ X$ represent the rainfall curve of a storm, of which the abscissæ are the time in minutes reckoned from the beginning of the storm and the ordinates the actual rates of rainfall* in inches per hour. Then, if the "time length" of the plane be M, the distance between the ordinates T and T', the maximum flow will occur at P when the area of the curve between the ordinates becomes greatest as they are moved over the curve M minutes apart, and will be equal to the product of the area of the plane and the average rate of rainfall between T and T'.

* The rates of rainfall for each infinitesimal portion of time.

This average rate is, of course, equal to the area of the curve between the ordinates divided by M.

In order that these results should hold exactly it would be necessary that M should not change for different values of the maximum flow and that the velocity over the plane should be uniform. This can never be exactly true, but since it is proposed to use these results for small areas only, the error is more apparent than real, and if corrections were made the ultimate results would be affected only to a very small extent. If the maximum flow is collected into a channel at the edge of the plane and conveyed to a corner C, the time and occurrence of the maximum flow at C can be determined in the same manner, if the distance between the ordinates be taken as $M + N$, N being the time taken by the water to flow the length of the channel.

Let us now consider the conditions existing in a sewer or channel, when several of these simple areas are drained into it. In Plate 1, Fig. 2, let A, B, C and D be such simple areas draining into the sewer $S - S'$ flowing from S to S'.

If the maximum flow from A occurs at the time T, the maximum flow at B has run off by the time the flood wave from A reaches B, that is T'. This area is then discharging at a rate due to T', that is the flow added at B is due to an average rainfall between the time length ordinates of B on the rainfall curve with the far ordinate taken as T', multiplied by the area of B. This combined flood wave passes to C, when another quantity of water is added equal to the area C multiplied by the average rainfall between its time length ordinates with the furthermost ordinate taken at T'', etc. It is possible that the maximum flow at any point will occur before the maximum flow from the furthermost area arrives, if the near areas are large and the more distant areas small. In this case the maximum flow would be equal to the maximum flow from the near areas plus a pre-maximum flow from the further areas. Suppose this were the case at D, then the maximum flow would occur when T''' was taken, so that the average rate between its time length ordinates was greatest, and the maximum flow would be equal to the sum of the maximum flow from D plus the pre-maximum flows from C, B and A, obtained by multiplying their areas by the average rate between their time length ordinates, the further ordinates being

PLATE 2.
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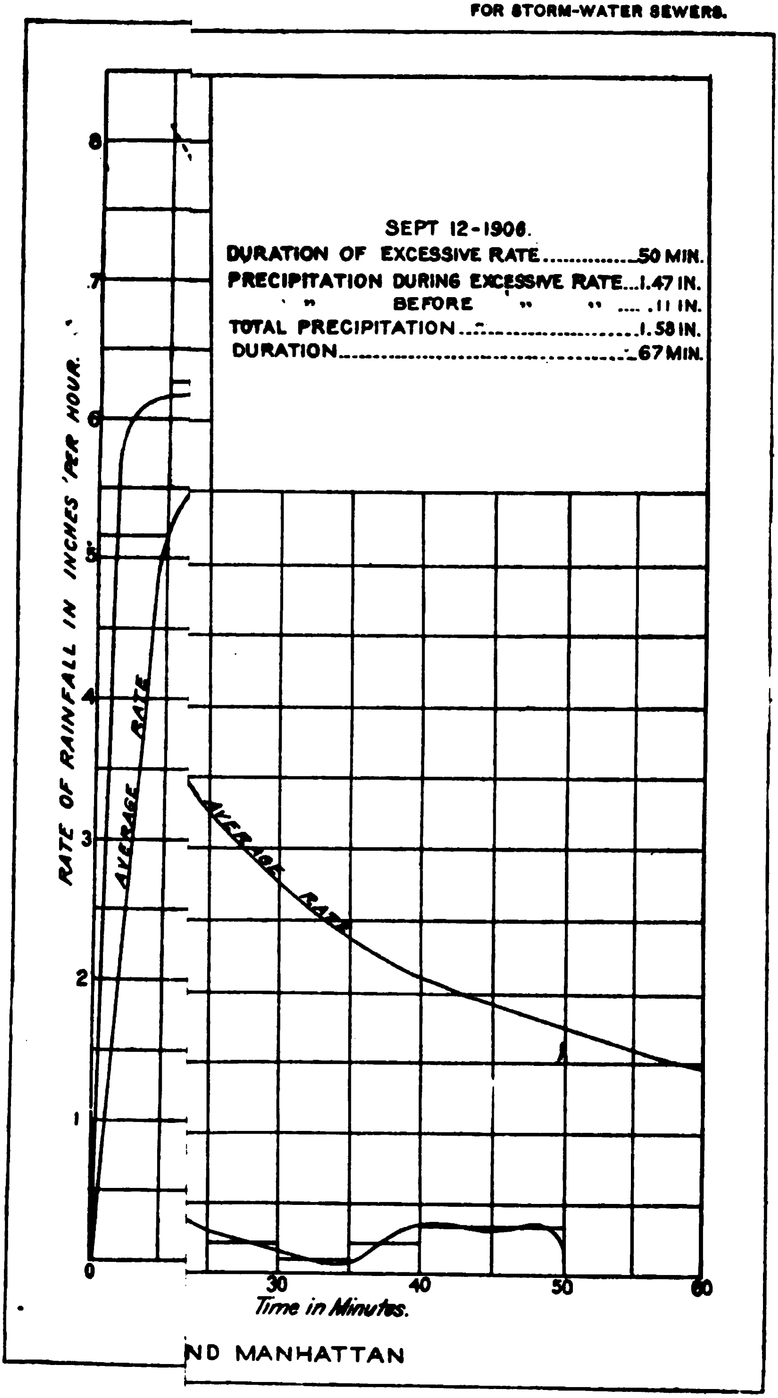

taken respectively at T'', T' and T reckoned from T'''. If the areas are unequal in time length and vary in size, the time and amount of maximum flow can only be determined by trial.

We can, therefore, determine very accurately the time of occurrence and amount of maximum flow from any complex area made up of such simple areas. In a drainage system these simple areas are in reality very small, such as sidewalks, courtyards, roofs, etc., but as hair-splitting accuracy is not needed we may consider an ordinary city block on the area draining into a catch-basin as being a simple area.

The primary point in determining run-off is in choosing a rainfall curve for which the sewers shall be designed. Fortunately we have at present fairly good data for this giving the average rates of rainfall for each 5 minutes of a storm. Formerly it was considered sufficiently accurate to take the average rainfall for an hour as a basis in sewer work, but it has been learned by costly experience that such data are almost worse than useless. When the great velocity in the sewers and consequent rapid concentration of storm water is taken into consideration the reason is apparent.

The storm curves shown on Plates 2 and 3 are plotted from the rain gage records of the Department of Water Supply, Gas and Electricity in Brooklyn, and the United States Weather Bureau's gage in Manhattan. The records of excessive storms were compiled by the Bureau of Sewers, Borough of Brooklyn, by whose courtesy they were furnished, and show the average rates of rainfall for each 5 minutes after the beginning of the excessive rate. Only five of the most exceptional have been plotted in the form shown here.

The curve marked "actual rate"* was drawn by a "trial and error" method in such manner that the average value of the curve between the 5-minute periods corresponds to the average 5-minute rainfall shown by the records. As this method allows considerable latitude in drawing in the curve, it is probable that the real curve differs somewhat, but pains were taken that it should be as simple and consistent as possible.

The curve marked "average rate" is the average of the preceding actual rates, and is the usual rainfall curve. It will be noticed that

* The rate of rainfall for each infinitesimal portion of time.

some of the storms have also a dotted line marked "highest average rate." This is due to the fact that in those storms the highest average rates occur after the storm has been in progress. For instance, in the storm of August 1, 1904, the average rate for the first 10 minutes was 1 in., but the average for the second 10 minutes was 3.6 in.

One striking feature of most of these excessive storms is that they occur almost invariably in the summer months when the conditions are most favorable for a large percentage of the rainfall being absorbed by unpaved surfaces. Only two have occurred in the winter months when the ground is frozen and practically impervious. Undoubtedly a curve could be chosen large enough to absolutely preclude any danger of the sewers ever being flooded by these storms, but it is doubtful if such procedure would be wise. In the first place, the initial cost of the sewers would be very great indeed, and in the second they would be ill adapted to serve sanitary flow if they were "combined sewers." In this city it has, I believe, been rather general practice recently to use McMath's formula with R taken as 3. Just how much rainfall this provides for is difficult to say; in fact it varies with the area. As will appear later, however, it seems to provide for a rainfall of 3 in. for about 11 minutes, and, of course, a lesser rainfall for longer periods. In order not to make too radical a change from present practice, the rainfall curve chosen for designing sewers in the Borough of Queens was taken for 3 in. for 10 min., and then decreasing in a curve whose equation is $\frac{600}{(T + 414)^2}$. This is, of course, the actual storm curve, and gives an average rainfall as follows: 3 in. for 10 min., 2.05 in. for 25 min. and 0.98 for 60 min. According to records of storms in Brooklyn from 1895 to 1906, inclusive, the 3-in. rate for 10 min. has occurred fourteen times, the 2.05 in. rate for 25 min. ten times and a 1-in. rate for 60 min. thirteen times. Six storms equalled or exceeded all three rates, seven storms equalled or exceeded the first two rates, and nine storms equalled or exceeded the last two rates. It is, therefore, probable that a system so designed will be flooded about every two years, when all the laterals are built and discharge from a territory sufficiently developed to give the assured percentage of run-off.

PLATE 3.
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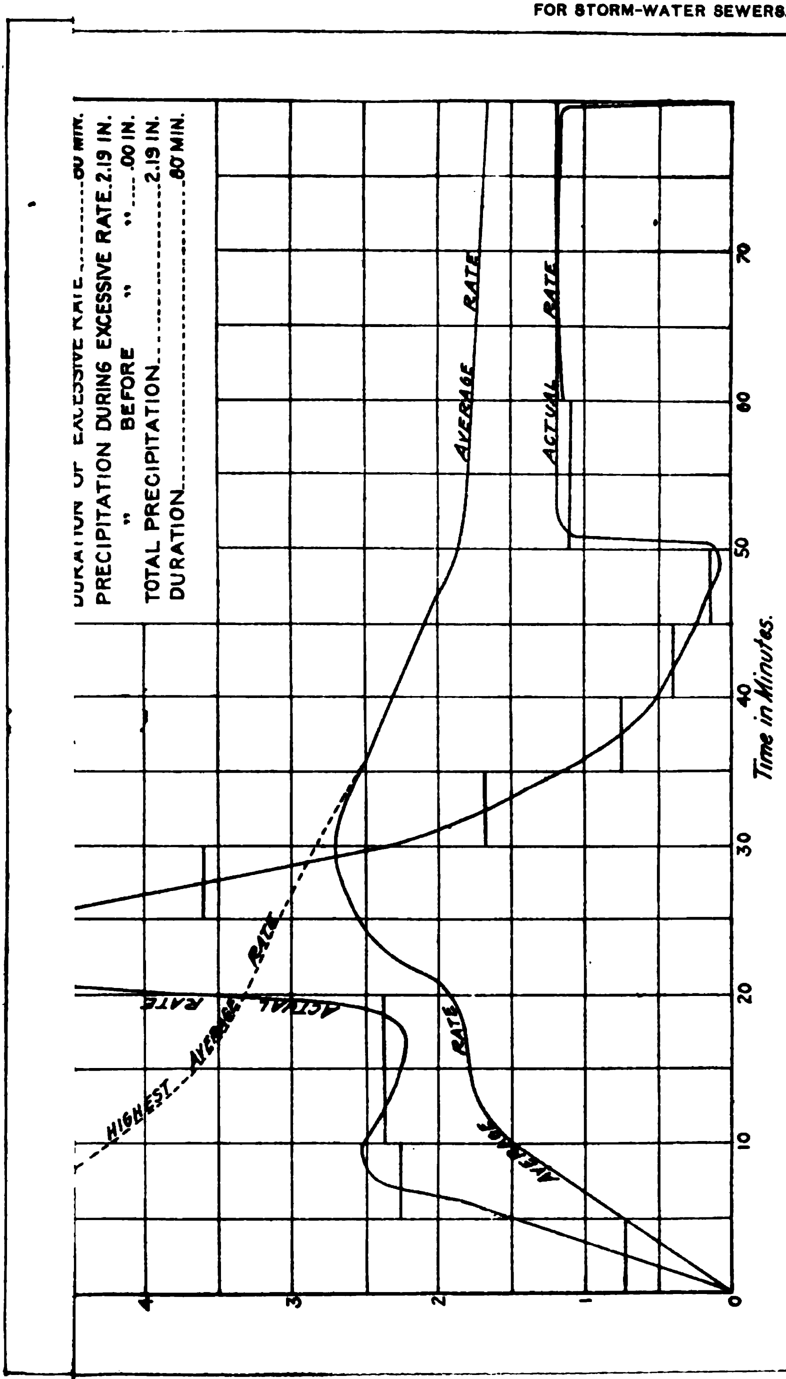

CURVE SHOWING RAINFALL RATES OF EXTREME STORMS IN BROOKLYN AND MANHATTAN.

In order to use the "additive method" it is necessary to know approximately the time length of the blocks, as they are to be considered simple areas. Unfortunately there are absolutely no data upon this very important point and it must be worked out from certain assumptions. Suppose a block 800 ft. long, 200 ft. wide, to be sloped so that the drainage is all to one corner from the corner diagonally opposite. The total length of run-off for the flow from the streets is then 1 000 ft. If the velocity in the gutter is 1.5 ft. per sec., the time of running for the 1 000 ft. in the gutter would be about 11 min., and if 2.0 min. were allowed for the water to flow the 15 or 20 ft. from the center of the street to the gutter, the total time length would be 13.0 min. for the flow from the street area. If the velocity in the sewer draining the roofs and yards is taken as 3.5 ft. per sec., and the time of running off the roofs and yards is taken as 2.75 min., the time length of the roofs and yard area becomes 7.5 min. As these data are based on assumptions that do not always hold true, it was thought better to use them rather advisedly, taking as the time length for both street and roof water combined, 10 min. for the average block 600 to 800 ft. long, with grades ranging from 5 ft. to 20 ft. per 1 000, and 5 min. for very short blocks or long blocks where the grades were over 20 ft. per 1 000. When the blocks were very much longer, or had a greater proportion of natural surface, this time length was increased to 15 or 20 min. Probably the assumption of 10 min. to the average block is too large and the real time is nearer 7 or 8 min., which means more rapid concentration and consequently greater run-off, but it was thought best to be somewhat conservative in this respect until more data are available.

One of the difficulties in using any method, involving the time of concentration, has heretofore been the labor involved in finding the time of running in the sewers. The velocity had to be obtained from tables which involved a product of several factors, and then the time in minutes was found by dividing the length of a sewer by the velocity in feet per second and reducing to minutes.

In order to overcome this difficulty the author designed a slide rule so arranged that if the length, drop and size of a sewer were known, one setting would give the time required to flow the given length (see Plate 4, Fig. 1). At the same time the rule has

been designed to avoid the necessity of reducing to a rate per cent. in order to find the capacity of a sewer. The rule is based on Kutter's formula, and correct positions on the scale worked out for $N = .013$ and $.015$ for brick or concrete sewers, and $N = .013$ and $.011$ for pipe sewers.

The use of the rule is as follows: Suppose at a certain point a quantity of 100 cu. ft. per sec. is to be discharged through a sewer 700 ft. long, whose coefficient of friction is .015. If 700 on the left-hand L scale is set under the required quantity 100 on the cubic feet per second scale, the different drops required by various sizes of sewers may be read off on the left-hand H scale over the divisions corresponding to the sizes on the line $N = .015$. If the coefficient of friction were assumed as $N = .013$, the rule would be set as before, but the required drop would be read on the left-hand H scale over the division on the line $N = .013$. It will be seen by the form of the rule that any coefficient may be interpolated by drawing lines connecting the corresponding divisions on $N = .013$ and $N = .015$, and also a line for N proportioned in by $N = .013$ and $N = .015$. By using the runner to project the intersections to the H scale the rule is read as before. If the sewer is established and the time of running wanted, the method of procedure is as follows: Find the drop of the sewer on the right-hand H scale and set it over the division corresponding to the size on the line representing the assumed coefficient of friction. The time in minutes may then be read off on the T scale over the division corresponding to the length on the right-hand L scale. With the same setting the velocity in feet per second may be read off by looking over the length on the left-hand L scale and dividing the reading by 10. The scales are adjusted for the sewer running 0.8 full; a point where the velocity is practically the greatest and the discharge 0.98% of the discharge running full, thus providing for a maximum rapidity of collection with a margin of carrying capacity. A scale is provided for converting the discharge for other depths of flow on the left-hand side of the rule, and a scale for converting the time and velocity on the right-hand side. The reverse side of the rule is graduated into logarithmic divisions so that it may be used for ordinary computations. The rule is manufactured by the Keuffel-Esser Co., of New York. It is 20 in. long, engine divided, the graduations being

PLATE 4.
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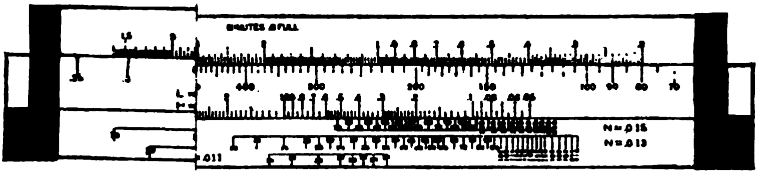
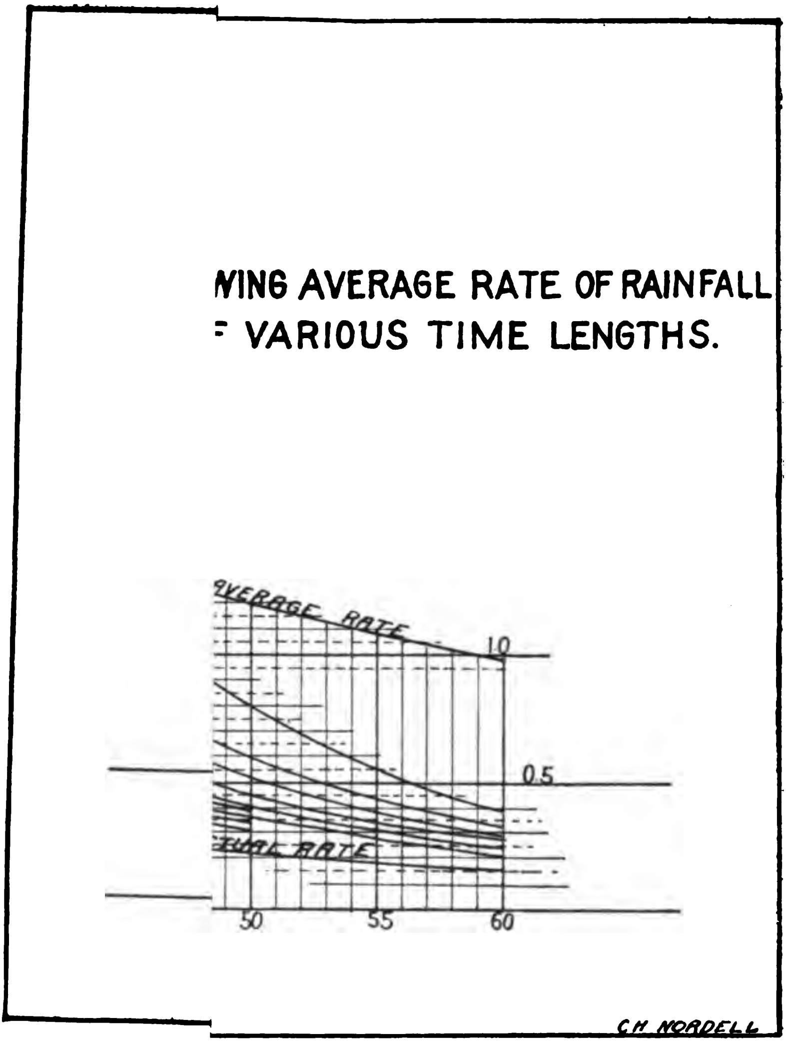


IOTHER. (NOT SHOWN IN CUT.)



in black upon a white celluloid face. By its use the labor involved in finding the time of concentration is so much lessened that to determine the run-off by the additive method requires very little more time than if a run-off formula were used.

In order to expedite the determination of run-off a diagram has been prepared which gives at any time the average rainfall on simple areas of known time length (see Plate 4, Fig. 2). In this diagram the inner curve represents the actual rainfall, the outer curve the average rainfall. The intermediate curves show the average rainfall on areas of the time lengths indicated. These were plotted from equations representing the average value of the rainfall rate between two ordinates moved over the actual rainfall curve, separated by a space equal to the time length of the area. Consequently, the discharge of any simple area of known time length may be found at any given time by multiplying its area by the value of the ordinate of its curve at the given time. The curves were plotted for 5, 10, 11, 12, 13, 14 and 15 min.; then for every 2 min. to 25 min. and then every 2.5 min. to 35 min.

Only two of these curves are generally used for separate blocks—the 5- and 10-min. curves, as their time lengths are not absolutely known and it is therefore useless to attempt much refinement. The other curves are for the purpose of determining at any time the discharge of a sewer which drains a number of blocks. It will be noticed that the rainfall curve does not commence at zero but rises from ½ in. to 3 in. at zero minutes. This is in order to allow a margin of safety if a pre-maximum rate of rainfall is considered, which occasionally happens in practice. A pre-maximum rate must, however, be used rather advisedly.

In order to use the "additive method" it is necessary to keep careful rates of each sewer determined, showing the acreage drained at each street intersection, the average imperviousness, the time of concentration, etc. The form of notes shown on Plate 5 is the one adopted in the Borough of Queens, and has been found to answer its purpose very well.

In the column headed A is shown the block acreage, including street and roof area, whose drainage is admitted at the point under consideration. I represents the coefficient of imperviousness, $T\ L$ the time length of the block, T the time at which the quantity dis-

charged is to be found, Q the quantity discharged at the time T. The total A is the sum of all the separate acreages, the total $A\ I$ the sum of the products of each acreage by its imperviousness, total Q the total maximum quantity to be carried, which, of course, occurs at the time T. The last three columns require some explanation. When the sewer discharges into another, the time of occurrence and amount of maximum flow for the two sewers combined must be determined. The time of occurrence will be almost invariably the time of arrival at the junction of the larger maximum quantity, and will be equal to the larger maximum flow plus a post-maximum or pre-maximum flow from the other sewer. In the diagram the maximum flow in the Tenth Avenue sewer is smaller than the maximum flow in the Twelfth Street and arrives at the junction 11 min. before the maximum flow from the larger sewer. It is clear then that the combined maximum occurs at the time $T = 35$, therefore the quantity added to the Q in the larger sewer is due to each of the areas discharging at a time 11 min. later than the time previously considered. Of course, this quantity might be obtained by calculating the discharge from each block for the time T plus 11, but in the case of a large sewer, this would involve considerable work. We can, however, approximate this quantity very closely by the following method. If we take the time of collection at the last point as the time length of the area and divide the total Q by the average rate of rainfall for that time we obtain the equivalent simple area. In this case the equivalent area is 28.3 and the time length 20 min. If we then multiply this equivalent area by the rate for an area of time length 20 at a time 11 min. after the maximum, or 31 min., we obtain very closely the discharge of the sewer when T-35 at Twelfth Street. It will be noticed that the total $A\ I$ for the Tenth Avenue sewer is 24.15, a smaller figure than the equivalent area 28.3. This is due to the fact that the greatest amount of territory is covered in the first portion of the 20 min.; consequently, a high rate of rainfall is collected from the greater portion of the area. If the collection were absolutely uniform the total $A\ I$ would of course have been equal to the equivalent A.

This then constitutes a very good check on the work as in most cases where there is a large difference between the total $A\ I$ and the equivalent A. The reason is apparent on inspection of the area.

FORM OF NOTES

LOCATION	A	I	TL	T	Q	TOTAL A	TOTAL AI	TOTAL Q	EQUIV A	T_1	Q_1	REMARKS
SEWER IN 10TH AVE. FROM 1ST ST. TO 12TH ST.												
1ST ST.	4.0	.75	10	10.0	9.0							
2ND ST.	5.0	.75	10	10.7	11.2			20.2				
3RD ST.	3.5	.75	10	11.2	7.8			28.0				
4TH ST.	4.0	.75	10	11.7	8.8			36.8				
5TH ST.	4.5	.75	10	12.5	9.7			46.5				
6TH ST.	3.0	.60	10	13.5	5.0			51.5				
7TH ST.	3.5	.60	10	14.5	5.6			57.1				
8TH ST.	3.0	.50	10	16.0	3.7			60.8				
9TH ST.	3.0	.50	10	17.5	3.3			64.1				
10TH ST.	1.0	.50	10	20.0	0.9			65.0				TIME TO 12TH ST. 4 MIN.
10TH ST.	2.0	.50	10	18.0	2.0	36.5	24.15	67.0	28.3	31	32.6	BASIN ON 9TH AVE NO WATER ADMITTED AT 11TH ST.
SEWER IN 12TH ST. FROM 10TH AVE. TO 15TH AVE.												
10TH ST.	4.0	.50	10	35.0	0.9	620	345	492	300			CONTINUATION OF 12TH ST SEWER Q_1 FROM 12TH ST. ADDED.

In some of the cases that have come up with actual areas the equivalent A has been 30% greater than the total $A\ I$ and in other cases it has been 15% less. With small areas whose collection is fairly uniform the difference is almost nothing, thus showing that for such areas, Kuichling's method of run-off determination holds.

The time of occurrence of maximum flow is not always the time of collection from the furthermost point of an area, but in practice such cases are usually apparent at first glance. Where any doubt exists, however, it is best to determine this by trial.

No corrections have been attempted for the velocity in the sewer varying with the quantity discharged. Luckily this variation probably affects the results very little until the sewer begins to run less than half full. After the discharge falls below one-half of the maximum the velocity becomes much less and probably the actual quantities discharged is somewhat in excess of those obtained by the method described above. It would, however, be folly to attempt corrections for this before the actual time lengths of the blocks are determined—a factor which has vastly more influence on the size of the sewer. If these time lengths were known fairly accurately we could undoubtedly design a system with a very small factor of error, providing the imperviousness were absolutely known.

The method can also be very readily used so as to allow for the velocity and direction of the storm over the drainage area by merely adding to or substracting from the time for which the discharge of the blocks are computed. For instance, suppose it were known that the excessive storms moved in the direction of the flow in a sewer. It is clear that we should then subtract the time taken by the storm to travel the distance between two points of admittance of storm water from the time of running in the sewer and use the difference as the time distance between the areas. If the storm moved in a direction contrary to the flow in the sewer we would add the time instead of subtracting and if it moved obliquely to the sewer its component velocity would be used in the same manner.

It will, perhaps, be argued, as the time of collection from the blocks is not known at present, that any method of run-off determination depending upon this time is valueless, but as this time error is probably not more than 2 or 3 min. at the most, the resulting error in the maximum flow is small in comparison to the error intro-

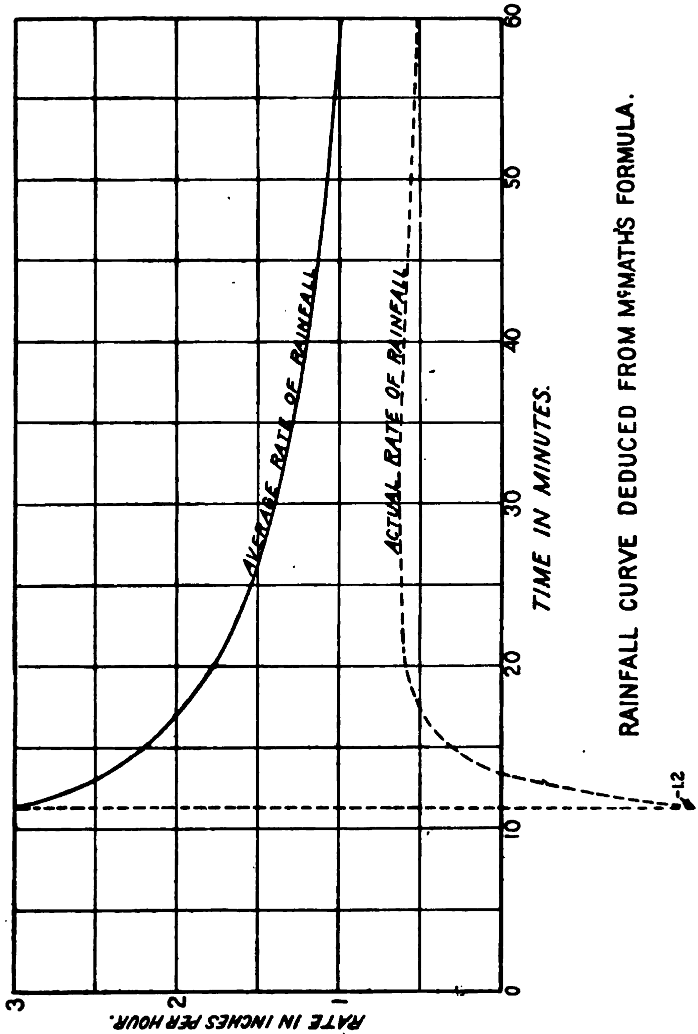
duced by using any run-off formula. For instance, an examination of McMath's formula proves absolutely that it cannot hold true even if the collection was uniform and the time of concentration depended upon the acreage and the average slope. Parmley, in his paper upon "Rainfall and Run-Off" before the American Society of Civil Engineers, deduced the rainfall curve of McMath's formula as $R = \frac{1.59\,r}{\sqrt[5]{(t-8)^2}}$ where $r = R$ in the formula, by considering the time of concentration to be $\frac{3.2\sqrt{A}}{\sqrt{S}} + S$. This is of course the average rate of rainfall. It is clear from the form of the equation that the curve passes through $\pm\infty$ when $t = 8$, which, strictly interpreted, would mean that the average rate of rainfall would be very high indeed for values of T a little greater than 8 min. If, however, we assume that the curve starts at the point $T = 11.2$, or the time required to drain 10 acres with $S = 10$, and take Y as 3, the average rate for the 11.2 min. becomes 3, which is a fair value. The curve does not, however, hold true beyond this point. For instance, the 3-in. rate for 11.2 min. means that that precipitation is 0.56 in. According to the curve the rate of rainfall for 15 min. is 2.18 in., which means a precipitation of only 0.545 in. Therefore, more rain is supposed to fall in 11.2 min. than in 15 min.—an evident absurdity. This can very readily be shown by plotting the actual rainfall curve as derived from the average rainfall $R = \frac{1.59\,r}{\sqrt[5]{(t-8)^2}}$. If this represents average rate of rainfall and if $r = 3$, $R = \frac{4.77\,t}{\sqrt[5]{(t-8)^2}}$ represents the integral curve of the actual rainfall curve. If the origin is transferred to 11.2 we have $R = \frac{4.77\,(t+11.2)}{(t+3.2)^{\frac{2}{5}}}$, and by differentiating we obtain the actual rainfall curve,

$$R^1 = \frac{4.77 - \frac{2}{5}\,\frac{4.77\,(t+11.2)}{(t+3.2)}}{(t+3.2)^{\frac{2}{5}}}$$

referred to $t = 11.2$ as the origin.

This curve and the average rainfall curve are shown on Plate 6. It will be noticed that the rainfall drops away to a minus quantity at 11.2 min., but soon redeems itself by climbing rapidly to the half inch rate, where it remains for some time. This analysis

PLATE 6.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
NORDELL ON RUN-OFF DETERMINATION
FOR STORM-WATER SEWERS.



RAINFALL CURVE DEDUCED FROM McMATH'S FORMULA.

may perhaps be met with the objection that the time is not really $\frac{3.2\sqrt{A}}{\sqrt{S}} + 8$, which in a way is well grounded. But, although this is true, it cannot be denied that it is conceivable that there are areas where the expression gives the time correctly. In fact, the author plotted the results from an area whose time of collection corresponded very nearly to this. In Plate 1, Fig. 3, the crosses represent the rates of rainfall as given by McMath's formula and plotted according to the time required for concentration. The time of the first block was taken as 10 min. instead of the 8 min. used by Parmley, with the result that the curve corresponds very closely with the curve he deduced, but is 2 min. further from the origin. As the initial time of running the first block is unknown, and the time of running in the sewers is known, the only error possible is one affecting the position of the origin. In order to overcome this, the curve was moved toward the origin until a point was reached where the actual rainfall curve would not have minus values and would decrease from the 3-in. rate in a fairly rational manner. This position was not reached until the time for the 3-in. rate was about 2 min. From the curve, however, the 3-in. rate applied to an area of about 40 acres. Thus, in order for the results to hold, the time of concentration for 40 acres must be 2 min.—which is rather difficult to conceive. If the portion of the curve with values of R greater than 3 had been considered, the result would have been even more absurd. It seems rather strange that so much time and labor should have been spent in the effort to establish a run-off formula. It is impossible, in the author's opinion, to devise one that will be even reasonably accurate without becoming unwieldy, as it would have to contain more variables than are allowed for in the present formulæ, and three of these variables are of such nature as to render it doubtful as to whether they could be embodied in a formula at all. For instance, we have seen that it makes a great difference in what portion of an area the highest slopes and greatest degrees of imperviousness occur. Then, too, the shape and manner of collection influence the run-off to a marked extent. Formulæ should never be used except as a rough guide to indicate what run-off may be expected, and even here their use could probably be dispensed with by estimating the time of concentration and considering the area to be a simple area.

Nothing more flexible than the method outlined can be devised; any rainfall curve may be used; the method adapts itself perfectly to all areas and any number of corrections and refinements can be introduced. For instance, the primary "simple areas" can be made as small as may be deemed necessary; the rainfall curve can be flattened to allow for the amount of water required to form a surface film and fill the gutters, being held back from the sewers for a time; the amount of water which goes to fill surface depressions can be subtracted from the beginning of the rainfall curve. Probably much of this refinement is not needed, but should it be found by experiment that any of the foregoing factors are important, they could also easily be allowed for. Should it be found by rainfall gagings that the intensity of the storms varies considerably as they move over an area, the rainfall curve could be increased or decreased as the time of concentration became greater. A series of experiments upon small areas, which could be made at a comparatively small cost, would determine most of these factors, but the rainfall gagings would have to be extended over a number of years in order to be of value.

The assumption of a percentage of run-off to provide for the expected development of an area presents a rather difficult problem. The typical development of the separate blocks can usually be estimated fairly well but in many cases it is almost impossible to foresee just what portions of the territory will be developed in the time the sewers are expected to prove sufficient. Probably the ideal solution of the problem is to build the laterals and small trunks large enough to take care of the run-off from the expected typical development, and intercept with sewers only large enough to provide for a part of this run-off, and so designed as to be easily relieved in the future. When for any reason this scheme is not feasible, the assumed imperviousness may be decreased in proportion to the area drained. For instance suppose the typical development of the blocks of area a to be such as to give a coefficient of run-off C; if the imperviousness from the whole area A were assumed as $N\ C$ at the end of time the sewers are expected to last, the run-off could be accordingly reduced to the expression $\frac{Q}{N\sqrt{\frac{A'}{a}}}$, where A' = the area drained by the

sewer, Q, the run-off if the whole area were developed into typical blocks, and M so taken that $\sqrt[M]{\frac{A}{a}} = N$, or according to the expression $Q\left[1-\left(\frac{N-1}{N}\right)\left(\frac{A'-a}{A-a}\right)\right]$. In the first case the total imperviousness would decrease from the maximum to the minimum in a hyperbola so that the decrease would be more rapid at first, and in the second case the decrease would be uniform, the locus being a straight line. Just what method should be used and what values assigned to A, C and N for any particular area, can only be determined by a careful study of conditions.

DISCUSSION.

MR. ROBERT R. CROWELL.—Gentlemen: This is one of the most interesting papers read before the Society and I would like to call on Mr. Schreiner, who is very intimately connected with this work in Queens Borough.

MR. ALBERTO SCHREINER.—Gentlemen: A couple of years ago a report was published on the question of the collection of storm water in the City of Baltimore, and in that report the different formulæ for run-off were very carefully discussed. The conclusion was that any one of those formulæ, the McMath, Burkli-Ziegler, or New York Diagrams, could safely be used. I took certain data in our work to determine certain storm-water sewers and found in using those formulæ that the variation in capacity of the sewers was nearly 40 per cent. The sewer engineer, who has to deal with that kind of formulæ, does not know if he is wasting the money of the community or if he is going to cause conditions like we have had in the last few years in Brooklyn.

I have heard some sewer engineers declare that they use McMath's formula because it is lucky. I have heard other men say, and I had the same opinion for a while, that the Hering formula, New York diagram, should be used because it was worked out from actual conditions in New York City. I do not doubt that to a certain extent those formulæ are very reliable, or would be very reliable if we knew under what conditions they were derived. Was the flow into the sewers measured right at the beginning of a rainstorm? Was the territory entirely covered with water? Was there a film of water covering the whole area? Was the atmosphere very moist or not before the storm? If we want an absolute run-off formula, it would be necessary that observations should be made under all conditions. Even then each area is an individual area in its different aspects, from the standard of artificial development, the nature and quality of pavements, how closely it is built up, the condition of the atmosphere, the shape and slope of the area, etc. Here we arrive at the weakest point of all those formulæ; they all include the same factor s, the slope of the area. Let us consider a single area of 100 acres, with an average slope of 10 ft. in 1 000. The chances are that 25 of these acres have a slope of 15%, 25 acres 20%, and 50 acres 8 per cent. If the furthest point of collection is at the end of the steepest slope, we naturally will have from one part of that area a very rapid collection and from the other part a very slow collection. The logical result is that the run-off formula is used for as small areas as possible; that is, to get as uniform conditions as possible over a certain area. As soon as you use a

larger area those conditions will vary to a great extent, and confidence in the formula is gone.

This matter of run-off has been discussed, to a great extent, in different technical societies, and there is the paper by Mr. Gregory on the question of rainfall. After all those discussions, the matter has always been left undecided. We are still guessing, as we did fifteen and twenty years ago, and it is about time that engineers should come to a conclusion. I think it is time for this Society to take up this matter of run-off, as it is a very important question in the City of New York, particularly in the Boroughs of Queens and Richmond, where, in the near future, more sewers will be built in a short space of time than in any other territory of the same size in the world. Engineers are now working on judgment, and to work only on the individual judgment of any engineer is bad policy. Judgment must go hand in hand with mathematical facts to give proper results.

MR. CROWELL.—I would like to call upon Mr. Gregory for a few words on this subject.

MR. CHARLES E. GREGORY.—This paper, in a concise and creditable manner, treats academically of a method of determining storm-water run-off by adding together the run-off from each of the several unit areas into which a watershed may be divided, so as to take into account the theoretical effect of variations in the intensity of rainfall of a certain assumed storm. It does not treat of other important factors which are necessary to determine the relation of run-off to rainfall. It is almost wholly theoretical and presents no experimental data to substantiate the theories. The slide rule brought out in this connection is very ingeniously arranged, and will prove invaluable for any method of sewer design in which the time length is used as a factor in determining the run-off.

The average rainfall curve assumed is shown by the data presented to be such that a drain designed to care for just such rains would be flooded once or twice each year, a condition certainly not to be desired. The proposition to flatten the run-off curve "to allow for the amount of water required to form surface films, etc.," is simply a confession of the inadequacy of the method to properly provide opportunity for "corrections and refinements," as the actual rainfall will not conform to the flattened curve, and the resulting curve is therefore no longer the rainfall curve. A rainfall curve once determined cannot be changed as such, neither should the relation of rainfall to run-off be changed, except to provide for different conditions, and then only with a thorough understanding of the influence which the changed conditions exert.

For the "rational method" it is not necessary to know the time length of each block. If the simple area assumed is small, it is not

important that it should be accurately known for the additive method. Unless the time required for the water to reach the sewer from the roofs and pavements at the most distant unit is known to be different from the nearest one, each may be assumed to be the same. A uniform 10 min. is assumed by Mr. Nordell. The variation in intensity of rainfall from one to another of each of these unit areas is due to the time it takes the maximum flood wave from the first area to reach the outlet of each of the others in turn, and is therefore independent of the time length of each.

Dividing the watersheds into small areas for particular consideration, and allowing for the rainfall rate on each to vary with the increasing time length as each such area is added, is the only safe method, and so far is similar to the rational method used in the Boroughs of The Bronx and Richmond, and was first proposed by Mr. E. Kuichling. The method presented differs from the rational method in that the curve of average rainfall, plotted to enclose many different storms, is changed to a single storm, whose relative rates are so arranged that at any time their average will equal the average curve. Like the rational method, the maximum average rate is taken from the first unit area, but for the succeeding ones a rate is taken which represents the average of the same storm for a period later than the average maximum and consequently of a less intensity. A different actual curve represents the rate for each unit area of different time length. The rational method is simpler, in that a run-off is determined from the maximum average rainfall for the time of flow from the most remote of the unit areas to each successive point considered, and thus all subsequent consideration of pre-maximum and post-maximum rates is eliminated. Modifications to provide for special conditions may be as readily made under the rational as under the additive method. In justification of his method, Mr. Nordell shows by the example of the Tenth Avenue sewer that the so-called additive method gives a greater run-off for the entire area than the average rate would have done, and assumes that this result shows greater accuracy, because of the increased flow from the steeper slopes at the remote end of the watershed. If however, the steeper and larger areas had been near the outlet, the reverse effect would have been obtained, *i. e.*, a less run-off than the average rate. Probably no rain storm ever occurred with intensities even approximating those assumed for the actual storm. The order of intensities might even have been reversed, resulting in even greater error. While an average rate may not be theoretically applicable to all storms and all watersheds, experiments have shown that it gives as close results as can be expected from the nature of the problem. There is much greater probability of error in assuming a variable rate, and Mr. Nordell is forced to practically abandon

the additive method as soon as the junction with the larger sewer is reached. At this point it is quite likely that a storm with intensities arranged very differently from the one assumed, will give a maximum run-off from the combined areas of the two branches.

If the additive method is to be attempted, and reasonably close results obtained, a storm with differently arranged intensities would have to be determined for a maximum run-off for each different shape and time length of watershed.

Mr. Nordell apparently assumes that the rate of run-off would be as great as the rainfall after the rainfall curve has been flattened to suit his judgment. In a paper by the speaker read before the American Society of Civil Engineers in February, 1907, are given the results of sewer gagings in New York by Mr. Rudolph Hering; in Rochester, by Mr. E. Kuichling; in Cambridge, Mass., by Mr. M. L. Hastings; and in Hartford, Conn., by F. L. Ford. These together with many personal observations of the speaker show that the rate of run-off from watersheds at the end of their time length is less than the average maximum rainfall for that time. On impervious areas, the ratio varies from about 0.3 for a 5-min. time length to about 0.75 for an 80-min. time length. On pervious or grass areas the ratio is much smaller and varies between wide limits. Mr. Nordell in his additive method in assuming a run-off equal to 100% rainfall seems to confuse the total run-off with the maximum rate of run-off.

The errors inherent in this method together with the utter neglect of the actual relation of rainfall to run-off make the method as presented much less reliable than a well-understood empirical run-off formula like Hering's New York formula or McMath's St. Louis formula, which are based upon actual flows in sewers.

MR. CROWELL.—Professor Folwell, have you a few words to say on this subject?

MR. A. PRESCOTT FOLWELL.—It has been a number of years since I really thought deeply on the subject of rainfall and run-off, but I still retain an interest in it and I was very glad to see Mr. Nordell was following out to its logical conclusion the rational method which, I believe, was first proposed by Mr. Kuichling and advocated by myself in the book I wrote some years ago. I think Mr. Nordell was perfectly correct in saying, and perhaps did not put quite enough emphasis on the fact, that the formula of Mr. McMath, which has had quite a little prominence and very wide use in this country, up to within a few years anyhow, really was never intended by Mr. McMath to be of general application. I think it would have been much more fortunate for the sewerage engineers and the profession generally if that had been called the St. Louis formula rather than the McMath. Mr. McMath told me personally

some years ago that he never had any idea that formula would come into general use and it was never intended for that. It was a formula, largely empirical, obtained from the results in St. Louis and was not supposed by him to be universally applicable by any means.

As Mr. Gregory said, I think it might be a good plan if the gagings of Mr. Hering could be adopted as the basis of calculations, or the use of the New York formula, but a formula for one locality no more fits another locality than the clothes of your President would fit me. I would probably be much more comfortable in his clothes than he would in mine, and the formula that will give you the larger value is to be desired more than the one that gives you the smaller value; it is liable to lead to less uncomfortable results. But the gentlemen who have already spoken have all said, I believe, that they think no general formula should be adopted, and I think that is getting to be the universal opinion now. It is a great deal easier, if you can do it, to take a formula and simply measure up the area and take your average slope and use coefficients obtained by investigations which were made within a thousand miles of where you are designing the system, and insert these values into a little formula of only three or four quantities and in 5 min. find out what the capacity of the sewer should be; but that really does not give you anything like accurate results.

I am older than I was fifteen years ago when I looked into this matter; Mr. McMath was older when he and I discussed the matter than he was when he made his formula, and Mr. Kuichling is older than he was when he advanced his; and both, like myself, appear to have come to the conclusion that it is not worth while splitting hairs too much in this matter. For instance, Mr. Schreiner stated that he calculated the results from a number of formulæ and found a maximum disagreement among them of 40%; and yet the Baltimore Commissioners said any one of them would do. That seems like a very large discrepancy, of course—40%—but the capacity of the sewer varies approximately as the $\frac{5}{2}$ power of the diameter. Consequently, of the two sewers, one having a capacity 40% greater than the other, the larger would have a diameter only one-seventh greater than the other; and in quite a considerable percentage of sewers the cost does not begin to vary with the diameter, so that two sewers, whose diameters vary by about one-seventh, probably would not vary in cost by more than one-tenth, so that it is quite within the realm of probability that those sewers, one 40% greater capacity than the other, would not differ in price by more than 10%, and 10% is not such a very large coefficient of safety in your expense account when you are a little uncertain.

When you come to consider that if you are going to be certain, you have to take rain gages and scatter them all over the territory in question and study the rainfall in that territory for years; that you not only have to study the territory as it is but must make up your mind what it is going to be in the next twenty-five or thirty years, while the sewer is in good service; and that there are several other conditions, such as the coefficient of velocity of the sewer, and other things which you are more or less uncertain about; then that coefficient of 10% does not cut such a very large figure after all, when you come down to that.

To take up another suggestion. I think there has been quite a little criticism in the last few years among engineers, and especially among citizens, of the making of the old Brooklyn sewers too small, so that millions of dollars have now to be spent on relief sewers. Possibly some of them will say: "What a fool Adams must have been when he designed those sewers in Brooklyn, and here they are not half large enough." Adams was not by any means a fool; he was a very bright engineer. In his day he did not have, to begin with, anything like the data we have to work with, and he did the best that the information he had at hand enabled him to do; but even supposing he had all the information, I think Mr. Adams would not have been justified in designing and constructing fifty years ago, when the streets were cobble, if they were anything more than mud, sewers which would carry rainfall from asphalt pavements all over the city; because during those fifty years or so, of the money which he would have sunk in the ground which would have been double what he actually did put there, half would have been losing the interest (or rather the bonds would have been drawing interest) and that half of the sewer would be doing no service whatever. For during the forty or fifty years those sewers were underground that money would have accumulated enough interest probably to build the relief sewers that have been put in within the last few years. The extra capacity can undoubtedly be placed to more advantage now than any foresight would have made possible at that time.

MR. CROWELL.—Will Mr. Reichelt, from Richmond, discuss this paper?

MR. VICTOR H. REICHELT.—There is one point in the paper on which I should like to have some further enlightenment, and that is the rate of rainfall considered for various time periods. If I understand it correctly, the author reduces the different rates of precipitation during a rain storm to an average rate, establishing a certain law for the rate of precipitation during a storm, starting with a maximum rate at a 10-min. period and gradually decreasing in severity. This rate as expressed by the curve of the average rate he accepts as a standard for the various rates of precipitation, which

may be expected in any individual storm, corresponding to the various time periods of the successive points of concentration along the sewer. Assuming that when a 10-min. area contributed water through the sewer at a rate of rainfall corresponding to a 10-min. period on the rainfall curve, at a point along the sewer which the water from this area takes 20-min. to reach, the additional sub-area contributing directly at this point will contribute at a rate corresponding to a 20-min. period on the rainfall curve.

We know that each storm follows a different rate of precipitation and that with very rare exceptions a heavy rate of rainfall, such as should be provided for in sewer computations, occurs but once during a storm. The storms during which such heavy rates of precipitation occur are with rare exceptions always summer showers, and rather sharply defined in their extent; that is, it will rain for 15 min. perhaps at the rate of 3 in. per hour and then will stop raining almost suddenly or reduce to an insignificant rain. The rain will not gradually die out at a rate analogous to the average rainfall curve as shown on the author's diagram, but will increase and decrease rather suddenly in intensity, so that when the rain-water from the 10-min. period area contributes its maximum flow at the point on the sewer which the water takes 20 min. to reach, the sub-area contributing directly at this point will not contribute water corresponding to a 20-min. period rate of precipitation, but at a very much less rate. The storms of great intensity and short duration will consequently only fill the tributaries of a sewer system extending over a large area, while a storm of less intensity but longer duration (being, however, a maximum on the rainfall curve for its period of time) will not fill the tributaries, but will fill the trunk sewer.

In the Borough of Richmond we have, for several years, used the rational method of sewer computation as outlined by Mr. Kuichling. The rainfall curve, giving maximum intensities of rainfall, the run-off of which we deem it advisable to provide for in the sewers, has an equation of intensity $= \frac{105}{T + 25}$, where T is the time in minutes. This curve does not take into consideration storms of extraordinary intensity, occurring at long intervals. The difference between the author's and Mr. Kuichling's methods appears to be that, while the author considers different maximum rates of rainfall at the successive points of accumulation according to the average rainfall curve designed by him, Mr. Kuichling considers a uniform maximum rate of precipitation for each time period of accumulation for the total area tributary to the sewer at the point of consideration, assuming that the maximum rate of precipitation occurring in a storm will rather abruptly change to a much lower rate and not

gradually decrease for a length of time equal to or approximating the run-off time of the watershed, which reasoning appears to be confirmed by the rainfall records of storms of great intensity.

As the author's table of computation did not contain a column showing the rate of rainfall considered in obtaining Q, it is not entirely clear to me what rates of rainfall he used in the computations.

MR. NORDELL.—Mr. Reichelt misunderstands the average rate. The average rate spoken of for those storms was the average of the preceding rates of that storm, not the average of all storms that occurred.

I think that the average rainfalls of all the storms is of very little value, because storms do not occur in averages; they occur one at a time.

MR. REICHELT.—You consider then that your rainfall curve provides for all maximum rainfall rates up to a certain maximum which you consider advisable?

MR. NORDELL.—No, this storm which I designed for is a theoretical one which I thought was large enough without getting too far away from present practice. The sewers which are designed according to that rainfall rate will undoubtedly be flooded by any such storms as shown by the curves, but the whole question is one of picking out a large enough storm if you want to provide for it.

This method is not such a great departure from Kuichling's. It only overcomes some of the inaccuracies in the theory of his method. In order that Kuichling's method should hold theoretically, it would be necessary that the collection be absolutely uniform, or that the rainfall be constant during the occurrence of the excessive rate. The first condition is very seldom met with in a territory over 50 or 60 acres, and as for the second I am certain that no rain ever fell in such a manner. In the typical storm curve, the highest rates occur near the beginning and are succeeded by lesser ones, until the rain ceases falling. It may be that the rate of rainfall again rises to the maximum, but this seldom occurs within the time required for concentration from most areas and may therefore be considered as another storm.

Sometimes the results obtained by Kuichling's method are identical with those obtained by using the additive method. At other times there is considerable variation. In one instance that I happen to recall the latter method gave a run-off 50% greater than the former. Surely it is worth while to allow for such a discrepancy when it can be done with practically no extra work.

MR. CROWELL.—Will Mr. Fetherston, of Richmond Borough, discuss this paper this evening?

MR. JOHN T. FETHERSTON.—For about six years, Richmond

Borough has used the so-called "Rational" method of sewer design, based upon Kuichling's general principles as modified by Prof. Folwell's practical application, shown in his book on "Sewer Design." The adoption of the "Rational" method in Richmond, or as Mr. Nordell has termed it, the "Additive" method, resulted from a study, analysis and comparison of results obtained by using the well-known formulæ of McMath, Hering, Burkli-Ziegler, etc. The principal indeterminate factor in the "Additive" method appears to be the time of concentration of the run-off from small areas, and it would seem desirable to have practical experiments made to cover this point. Some observations on the flow of water in gutters were made in Richmond by Mr. V. H. Reichelt and further observations are under way.

Mr. Nordell is to be congratulated upon his method of handling the subject and the additional information which he presents.

MR. CROWELL.—Has Mr. Arthur S. Tuttle anything to say relative to this paper?

MR. ARTHUR S. TUTTLE.—The paper of the evening is certainly a very interesting one, and it seems to me that the author is on the right track toward the solution of the problem of sewer design.

If we knew the maximum rate of rainfall, the maximum time required for concentration, the extent of the impervious area, the degree of imperviousness, and the slopes of the contributing area, there is no question but that a sewer could be planned which would be adequate for the prompt removal of all storm water. It will be noted, however, that only one of these elements is susceptible of precise determination with any degree of assurance that the solution is a permanent one, and it is evident that if all sewers were to be originally designed to meet the greatest storm that might reasonably be expected, and under the assumption that the territory was fully developed, it would require sizes which, for suburban areas, would involve a prohibitive cost.

By reason of court decisions which have placed the liability upon the City for all damage resulting from sewer overflows, there has been a tendency in recent years to increase the sewer capacity in all designs prepared for the drainage of territory within the limits of the City of New York, and in many cases I believe that the increased capacity will not be required until after the lapse of a great many years, when it is probable that further increases in the size of sewers will be considered as desirable to meet developments which cannot at this time be anticipated. It therefore seems to me a serious mistake to anticipate future growth beyond a reasonable extent, and that while recognizing the ultimate needs in so far as general lines of drainage are concerned, and also the readjustment which will later be required, our sewers should be planned, and

particularly in the suburban sections, to have a capacity sufficient to meet the probable normal growth and needs of the territory during a limited period, and that this term might well be extended for the urban sections according to the degree of development and the expense to which property owners may be subjected without requiring an expenditure greater than they could be reasonably expected to bear.

There appears to be no reason why this course should not be followed and at the same time the City's interests fully protected, if the drainage plans were in each case to be qualified in such a way as to indicate that they were not intended to provide a sewer capacity adequate for the complete development of the sections or to promptly remove all storm water, but that they were prepared with due regard to the immediate needs of the territory affected and to the justifiable expense of the improvement. This treatment would require a recognition of existing conditions in the various boroughs and in parts of the same borough, but it does not explain the great differences in method now employed in the various boroughs for solving problems of the same nature. It is remarkable that with the great interests of this municipality in the preparation of adequate designs for drainage, so many important factors can only be approximately estimated and that so many of them are based on experience other than that resulting from local investigations.

MR. CROWELL.—Is it not a fact, Mr. Tuttle, that the property in the suburban districts could not stand an assessment for a sewer large enough for its ultimate needs?

MR. TUTTLE.—I think there is no question about it.

MR. CROWELL.—Is there anything more to be said upon this question?

MR. REICHELT.—I would like to make a motion that this Society should do something to bring about certain experiments for the measurement of run-off in sewers. That is a subject on which very little has been done. Observations were made by Mr. Hering in the '80's on the Sixth Avenue sewer and in Rochester by Mr. Kuichling, and these are about the only exhaustive studies made by engineers, of the relation of rainfall to run-off in sewers, of which reliable data are available. I think that this subject should be taken up by the society and that observation stations be established in certain districts, which would be a standard in their class; in business districts, entirely built up; in residential districts, entirely built up; and in suburban districts. Such investigations would certainly give a great deal of information on a subject which now is, to the engineer on sewer design, a little more than guesswork, the amount of run-off from the rate of rainfall. It would be necessary, of course, to have rain gages in each district and a number of gaging

stations along the sewer, but there are in most built-up sections of New York and Brooklyn and other places, very good chances to do this kind of work.

MR. GREGORY.—I think it is a very important matter for New York City to take up this project. In fact, it is the only way to hope to get anything like a determination of all these variable factors which have been guessed at to a greater or lesser extent up to the present time. It seems to me New York City cannot afford to be longer without such data.

One of the speakers states that gagings in one city are absolutely worthless for work in another. I would like to take issue with that statement. I think that run-off from a given rainfall on any impervious area in any city should be constant. The rainfall curve can always be determined in a locality, and, having been determined, the amount of run-off from the impervious or similar surfaces should be practically the same in all places.

MR. GEORGE L. CHRISTIAN.—The contention of Mr. Reichelt and Mr. Gregory as to the need of sewer gagings are particularly *apropos* at this time. The City of New York should have undertaken such an investigation, and on a liberal scale, many years ago, and had they done so the citizens would have been saved many thousands of dollars. Thus far nothing of moment has been attempted in this city along those lines, except the investigations made by Mr. Rudolph Hering on the Sixth Avenue drainage area in 1889.

Facts are what is needed. Theory is all right in its place and if based on proper assumptions and a correct reasoning, a proper solution will be obtained. Theory, however, backed by facts secured from careful gagings of the sewers and measurements of the rainfall on certain drainage areas, made by capable men qualified by education and experience to intelligently apply the data collected, will be doubly fortified and will stand on unassailable ground.

Every drainage area, within certain limits, is more or less a law unto itself, and what would apply to The Bronx with its rocky formation and steep slopes, would not exactly apply to the sandy soil and flat slopes of parts of Long Island. The data obtained by a proper gaging of the sewers on certain typical drainage areas in The Bronx, Brooklyn, Queens and Richmond, together with a record of the rainfall on said areas, would be invaluable to this municipality and for other cities for many miles around. There is, however, a limit to the area over which such gagings would be of value, and what would apply to this part of the country would not exactly fit the Rocky Mountain region, for instance, with its different climatic and hydrographic conditions.

The measurement of both the sewers and of the rainfall should

be made with self-registering time gages. Those registering the rainfall should be located not more than half a mile apart, and there should be at least two or more on a given drainage area.

Some years ago the speaker had need for records of a certain storm to use in an investigation he was then making in connection with the overflowing of the Brook Avenue outlet sewer, which brought forcibly to his attention the great dearth of self-registering rain gages. There was none in The Bronx, while in Manhattan the nearest one was located at the Central Park Observatory. Subsequently the Bureau of Sewers of the Borough of The Bronx established two of these gages, which action is to be commended, although the number is still wholly inadequate, they being the only ones in the borough.

The speaker congratulates Mr. Nordell on the paper he has written, although he cannot agree altogether with the conclusions reached.

Mr. Schreiner.—Would the proposed gagings be made at the point of collection of certain general areas, or at all the points of the small section areas? If they were made at the point of collection of the large area, the results would be of absolutely no value, because in the next identical area for which you want to design sewers, the size of the sewers will depend not only on the extent and type of the area, but also on the sewer designed, on its slope and on the time of collection from the sewerage system itself.

Mr. Edwin J. Fort (by letter).—The problem of devising a formula upon which to base calculations of the flow of water in open channels would seem to be by comparison with the one we are considering a comparatively simple one, yet Gallileo considered it more difficult of solution than the movement of the stars, and Messrs. Ganguillet and Kutter, both of whom were accomplished mathematicians, with the results of extensive stream gagings, made under almost all conditions at hand, labored several years upon the formula which we now use. It seems to me that we underrate our problem, and I believe the tendency is to attempt too much in the short time that can be given by most of us to the subject. An addition, however small, to the positive knowledge of the subject is worth much more than theory. It seems as if we have theory enough and every attempt to branch out upon entirely new lines, unless the author is prepared to make an effort comparable with that of Ganguillet and Kutter, is to be deprecated. The same amount of energy spent in the last few years in attempts to evolve new theories, if spent in experimental work, would have added materially to the knowledge of the subject. I think that the paper written by Mr. Nordell and the discussion which has followed, while it contains valuable matter and many statements which show that

the author and those who have discussed the paper have given the subject careful consideration, does not on the whole show a proper appreciation of the intricacy of the problem with which we have to deal, and the paper in particular does not lay sufficient stress upon the necessity of basing all formulas upon the results of observation, and the absolute worthlessness of all theorizing unless conclusions are upheld by observations. Any formula worthy of entire confidence must be largely empirical, and it should be founded upon the results of experiments carried out through a series of years and over a wide range of territory where all conditions to be met with in practice may be found.

Twenty years ago Kuichling evolved, in connection with the design of the "East Side Sewer" in Rochester, what he named the "Rational Method" of storm sewer design. Certain principles were laid down which have generally been accepted as true. After rather extended observations, which, however, were crudely made, as no automatic rain gages were used and no careful gagings of sewer flow or accurate determinations of time required for concentration at sewer inlets were made, a formula was recommended for general use. This was the most notable contribution that had been made to the subject in some years and perhaps more notable than any that has been made since that time. A description of this method and the studies leading up to the conclusions arrived at are quite fully set forth in the Rochester Water-Works Reports for 1890, and in Vol. XX of the *Transactions* of the Am. Soc. of C. E. This formula or method of design has never come into general use, because vital factors entering into it are not known and must be determined by experiment. For instance, it is necessary to know the time required for storm water falling upon both pervious and impervious surfaces to reach the sewer under various conditions found in actual practice.

It is necessary to consider, in the case of small sewers especially, that storm water does not enter the sewer through basin or street inlets only, but through house connection drains from roof areas and at unequal intervals along the line of the sewer. When the district is fully developed the points of delivery are so unevenly spaced that theory alone cannot help us to a reliable conclusion, and little confidence can be placed in any method of procedure which has not been carefully checked with a long series of actual gagings. It will be found that comparatively small differences in the assumptions of time of delivery of storm water to the sewer will make large differences in the size of the sewer by the time the outlet is reached. Considering the lack of reliable information on this one point alone, I am surprised to learn that this method has been used in one of the boroughs of this city for some years.

As indicating the lines along which further effort should be directed and a definite method of procedure when all experimental data required is at hand, Mr. Kuichling's work is about all that can be desired. Further refinements upon his work before we have the means of verifying the different steps taken seem premature.

This paper, while it purports to advance a new theory and a new method of procedure, deals almost entirely with some of the details of Mr. Kuichling's work, and proposes modifications and refinements. It is a question whether they will be found advisable. Such refinements can be made with confidence only when experimental data are at hand to check each step taken. The further we differentiate, the nearer first principles we go for ground upon which to base our assumptions, the smaller our error is likely to be, but the likelihood of making some error will be increased, and this error, though small, will assume greater proportions the greater the number of times it is multiplied to reach the final result, and the further we shall fail in checking the results of actual gagings. It seems remarkable that the results of no extended gagings have been made public since those of McMath or those made by Mr. Hering upon the Sixth Avenue sewer in New York, or since Mr. Kuichling's report in 1890.

Let us have experimental work first and theory fitted to the facts afterward, since after all our formula must be empirical, the nature of the problem not admitting of exact mathematical analysis. A number of engineers in the neighborhood of Boston are preparing to make gagings upon drainage areas in various towns and cities, and I believe the same work should be started in every borough of this city.

Many disparaging comments are made upon McMath's formula, but there is much better reason for its popularity at the present time than that it is lucky. It is at least significant that the author of a new theory almost invariably hastens to compare its results with those of McMath, and its accuracy and general excellence are largely judged by the closeness with which it agrees. McMath's formula is deservedly popular because it represents the facts in the case of a large number of carefully made gagings. On this account alone it is worthy of more confidence than many untried theories, no matter how mathematically beautiful they may be. It is frequently said that it takes no account of time, but it should be remembered that time is a function of slope and of area; that the drainage areas upon which these observations were made were by no means all of the same shape, the same slope or the same area; that time does not vary directly with the ratio of the width to the length of the area, the route of the sewer being generally along the two sides rather than the hypothenuse of the figure, and last but not least

that it is not necessary that the time factor be represented by a separate symbol to insure that it is adequately taken into account in an empirical formula. It is also just possible that errors are sometimes made in applying the formula. It is undoubtedly true that observations made in one city are not always safe to use in others, but possibly we lay too much stress upon this fact. The character of impervious surfaces in American cities is quite uniform. Asphalt pavements, tin roofs, cement and stone walks are everywhere the same. Connections to the sewers are similar everywhere. The various conditions of pervious areas can be found everywhere, and surely the laws governing the flow of water in open channels and over surfaces do not vary with the locality. The character of storms does vary with the locality, but, after all, intensity and duration are the principal features that interest us. We may as well recognize the fact that inasmuch as all our sewers are designed for the future and no man knows what the future may bring for all localities in the way of development, the engineer's judgment must largely determine the basis upon which the design is made.

Forty or fifty years does not seem too long a time to look ahead, especially in our large cities, and if suburban property cannot bear the expense of a system sufficient for such a period, then perhaps the time has not arrived when sewers are necessary and should be built. A system which has to be relieved every few years, which is in places insufficient before it is finished and must be patched and rebuilt continually while private property is flooded and destroyed, is no system at all and does little credit to its designer. We should remember that our most primitive device for the disposal of household wastes, the cesspool, is the most expensive of all systems.

It is to be deplored that the same methods of design are not followed in all the boroughs of this city, but it does not follow that we are all wrong, or at least if we are, we may be comforted in our erring ways by the companionship of some of those who are foremost in the profession.

Mr. Nordell (by letter).—The paper as presented is not intended to be anything more than an exposition of a method of run-off determination. It is not possible to present data that would make its application strictly correct, for the very simple reason that, as far as I am aware, there are no such data in existence. The lack of these data constitutes the errors inherent in the additive method, and some of the errors inherent in other methods of run-off determination. Mr. Kuichling's method depends upon these experimental data fully as much as does the additive method, but the time of draining the roofs and streets is used only for the first block—"the furthest point"—and is disregarded in the succeeding blocks. The same co-efficient of run-off or imperviousness is used in both

methods, and it is hard to see where in the method developed by the writer there is "an utter neglect of the actual relation of rainfall to run-off."

That the additive method is not abandoned when the junction of two sewers is reached is easily proved by referring to the form of notes shown on Plate 5. It is obvious, as Mr. Gregory states, that a rain storm of differently arranged intensities will produce quite a different maximum flow, but whereas the additive method is based upon the most probable arrangement of intensities deduced from a study of rainfall curves, Mr. Kuichling's method depends upon the intensity being uniform during the time required for concentration.

The sewer gagings mentioned by Mr. Gregory, while made by very able men and undoubtedly valuable in determining the run-off from the areas gaged, do not present sufficient data to make them generally applicable. In order that they might be analyzed so as to apply generally, it would be necessary to know the location, size, grades and character of all sewers, the character and grades of all streets, the location of catch-basins, etc., in the gaged territory, together with the continuous rainfall records of each storm and the continuous record of the flood wave in the sewer. With this given it would perhaps be possible to analyze the gagings so that the results might be used for any territory. It is all very well to lay such stress upon experimental data, but unless such data are determined so as to apply generally, their value is slight.

I hoped to show just what data are necessary for a truly rational method of sewer design, viz.: the time of drainage and coefficient of run-off from the small areas to the sewers, the typical storm curves, the amount of water necessary to form a surface film and fill the gutters and conduits, etc. These factors once determined, the additive method becomes correct in its application to any territory. Even though much of these data is not known at the present time, I confess that it is difficult for me to see why engineers using an emperical formula, designed for some city where the rainfall intensities, storm habits, and physical characteristics of the drainage districts are entirely dissimilar, should insist that the results are better than if a rational method is used, and the unknown factors estimated.

THE MUNICIPAL ENGINEERS
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SOME INTERESTING AMERICAN TREES.

BY HERMAN W. MERKEL.*

WITH DISCUSSION BY

ROBERT CROWELL, ERNEST L. MANDEL AND HERMAN W. MERKEL.

GENERAL.

Trees are the noblest and most beautiful product of the Vegetable Kingdom, the largest of all living beings, and the oldest living inhabitants of this earth. Eons before the advent of man, trees existed upon by far the larger portion of the land, and let us hope that they may continue to stay with us, for nothing has ever contributed to the welfare and comfort of man more than they, nor could we ever have obtained our present state of culture and civilization without the shelter, the help, and the fostering care which the trees have bestowed upon us. From the cradle to the coffin poor and rich alike are daily, yes, hourly, depending upon some product of the tree for food, fuel, shelter, drugs and many other necessities of life. The first step of man toward civilization, the use of fire, could never have been taken but for the abundance of fuel furnished by trees.

Ancient peoples have ever held the tree sacred and protected it from injury, realizing the benefit they derived from this policy. Unfortunately we of modern times have not continued in their footsteps. It is, however, time that we should generally recognize the fact that we must stop the reckless waste of our natural forest

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wealth, and begin to take care of what little we have left. We are now using our trees 3½ times faster than they are growing, and are taking no care to reforest the areas denuded, so that this ratio will rapidly increase. We are yearly permitting millions of dollars worth of trees to be destroyed by fire, and are standing idly by, while through wasteful lumbering, 50% of the useful wood is left on the ground to encumber the forest and to serve as a fire trap, and thus destroy forever the fertility and usefulness of the land.

Let us profit by the experience of China and of Palestine, two countries once well wooded, and now the most forsaken on earth, in comparison with which our American deserts look like the Garden of Eden. Let us profit by the experience of France, who was as destructive as we are, but found in the fullness of time that her rivers were being destroyed as useful waterways, and her farms ruined by the millions of tons of silt washed down by the yearly floods which the denuded hillsides could no longer control, and who was compelled to expend two hundred million dollars for reforestation. Let us profit by the example of Germany and Switzerland, where the need of rational and scientific administration of forests was recognized as early as the year 1700, and where not only the costly consequences have been avoided from which the more wasteful nations have suffered, but where a steadily increasing revenue of large proportions has been received from the forests by private owners as well as by the government. Our own forest service is doing great things—many of them in the nick of time—but it needs the support of every well-minded citizen and the hearty co-operation of our lawmakers, which latter, I am afraid, is often sadly lacking.

Trees are highly organized beings, composed like ourselves of millions of cells, that are carrying on their functions of assimilation or reproduction, according to their kind. It may even be said that trees have lungs, stomachs, and brains, though they carry them differently from ourselves, since the brains are in their feet and their stomachs in their lungs, and both of these are where we have our heads. This sounds queer, but let me explain. Their roots, which are surely their feet, go prospecting for moisture in which their food is dissolved, often traveling long distances in all directions, and having found it absorb only such kinds, and in such quantities and proportions of food as are good and useful to them. That is more

than some of us do, and certainly shows the possession of brains. As to carrying their lungs and stomachs in their heads, which are their leaves, the green cells of the leaves carry on the work of digesting the crude sap that is absorbed by the root and carried to them by the cells of live sapwood, and return the same as digested sap to form new cells. The leaves also absorb air through the minute stomata or breathing pores of which about 100 000 may be found on an average apple leaf, and exhale vapors no longer of use to the plant, so that they surely are lungs as well as stomachs.

All trees growing upon our half of this continent belong to the flowering or Phanerogamous plants, and may be divided into two classes, "inside growers" and "outside growers," the differences of which are very apparent. The endogens, or inside growers, are represented with us only in the palms and yuccas, and are named inside growers because the increase in size takes place throughout the whole trunk or stem, while with the outside growers or exogens, the increase in size consists of an additional layer of cells placed annually on the outside of the old ones. These annual layers of cells are readily distinguished because the spring cells are very much larger than those made during the latter part of the growing season, when circulation is not as active as before.

The cross-section of a trunk of an exogenous tree not only reveals the age, but also to a very large extent the life history of the tree, such as the passing through good and bad seasons and the rate of growth.

In the section of an endogenous stem we see the whole of the stem as one mass, showing no distinct layer, while in a cross-section of an exogenous stem, the annual layers may be clearly seen. The wood of the last few layers, through which the sap is still circulating more or less, is called alburnum or sapwood, while the older and dryer dead center is called duramen or heartwood, and this latter is often readily recognized by its change of color. In addition to this annual layer of wood, another layer is formed, but toward the outside, and this becomes bark.

HICKORY.

The hickory is a tree distinctly North American, not a single species being now found elsewhere, though we have 19 species here.

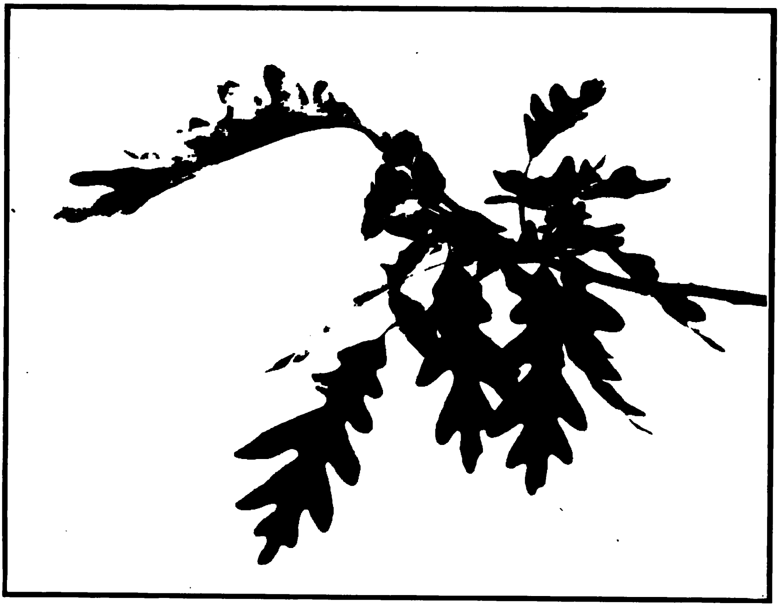

FIG. 1.—WHITE OAK ACORNS. THEY RIPEN THE FIRST SEASON.

FIG. 2.—RED OAK ACORNS. THEY RIPEN THE SECOND SEASON. THE SMALL KNOTS ON THE AXILS OF THE LEAVES ARE THE ACORNS OF THE PRESENT SEASON.

The best known of these is probably the "Shell Bark." The tree grows to a height of from 75 to 100 ft., and has attractive green foliage that turns to a beautiful golden shade in the autumn. Its useful fruit is so well known that I need not describe it here. The wood of the hickory is among the hardest known, weighing 52 lb. to the cubic foot, and is very useful for vehicles and tool handles, and makes the very best of fuel. The "Pignut Hickory" is another beautiful tree. Its erect habit of growing is one of its characteristics.

The Apple.

The apple is not a native of this country, but as it has four native brothers here, in the crab apples, and is so extensively grown, we may well consider it. Originally coming from western Asia, this tree has spread, in its improved form, throughout the temperate zones of the earth. When allowed to run wild the seedlings quickly revert to the type bearing small insipid fruit on scrubby, almost thorny trees, though a few varieties come true from seed. The apple is a slow grower, with tough wood that is very hard and durable. It is used for tool handles, levers, and imitation briar wood pipes.

Sassafrass.

The Sassafrass is a beautiful American tree, flowering and leafing very early. It is closely related to the Laurel or Bay tree of the Mediterranean. Its brown wood is weak and soft, but durable in contact with the soil, and therefore useful for posts. It weighs 31½ lb. to the cubic foot. Its leaves are of great interest, of which three forms exist, one entire, and the others 2- and 3-lobed respectively (see Plate 12, Fig. 1). They are very aromatic, as is also the bark, especially of the roots, which yield an oil used medically.

Oak.

The most important of all of our hardwood trees are the oaks, of which over 60 varieties exist in North America, distributed from Maine to California and from Florida to Canada. The best known eastern species is the "White Oak," a truly noble tree in proportion and aspect, with wide spreading limbs of picturesque and sturdy character (see Plate 8). Its wood is hard, strong and very beautiful, especially when quarter-sawed; it is used in ship building,

cooperage, furniture, interior finish, railroad ties, etc. It is now getting yearly scarcer and dearer, so that often inferior kinds are used under the name of white oak. The bark is used in tanning, and is considered better than any other for this purpose. The leaves are light green with a gray lining, turning to various shades of red in the fall. The acorns of this and several other species of oak, ripen the same year in which they set (see Plate 7, Fig. 1). The trunk, whose maximum diameter may be placed at 9 ft., is clothed in light gray bark, which is rough and sometimes scaly.

Next in importance in the Eastern States comes the "Red Oak," a tree with much darker bark than the white oak and dark green foliage, which turns to the most vivid red in the fall. The acorns take two years to ripen and are easily recognized by the very flat cup. Plate 7, Fig. 2, shows acorns of two years growth ready to drop, and small ones which will ripen next year. The wood is coarse grained, reddish, hard and tough, but not as beautiful as that of the white oak. Plate 11, Fig. 1, is a cross-section of the wood of the Red Oak, and shows clearly the prominent "pith rays," which make the silver grain when the wood is quarter-sawed.

The "Pin Oak," or "Swamp Oak," is a tree that will stand more abuse than any other oak. It will adapt itself to many soils and situations, and will thrive upon the dryest hillside, though primarily a swamp-loving tree. Its wood is very much like that of the Red Oak, and like it, its leaves turn bright red when winter approaches. The "Swamp White Oak" is another fine species, of beautiful outline and foliage.

In the warmer States the evergreen "Live Oak" charms all visitors, and draped, as it usually is, with long gray beards of Spanish moss, it well deserves at least honorable mention among our many beautiful trees. The wood of this oak was formerly much used in ship-building on account of its great strength and toughness. The first forest reserves in the United States were made early in our history for the purpose of insuring a permanent supply of this wood for our navy. Now, of course, steel has taken its place.

BEECH.

In smoothness and beauty of bark the "American Beech" yields to no tree, though one who knows this tree only by seeing it in city

WHITE OAK, A TREE OF NOBLE PROPORTIONS AND ASPECT.

parks, would hardly think so, for there its bark is generally scarred and wounded like the face of a German student, for lovers and those that will be or have been lovers like to carve their names upon it. The foliage is thin, bright green and silky, and often hangs dried, bleached, and rustling in the slightest breeze, through the entire winter months. The flowers are small and inconspicuous, coming out early in the spring, the staminate ones remaining on the trees only a few days. The pistillate flowers are generally carried in pairs. The fruits are commonly called beech-nuts. They are enclosed in four-valved burrs and are rather small in this vicinity, though growing larger further north. They are of a rich flavor, and contain an oil not surpassed by the finest olive oil. The wood is hard and close-grained and of a red-brown color. It is not durable in contact with the soil, but is useful for furniture, tools and as fuel.

Hornbeam.

A dainty little tree is the "Hornbeam," sometimes called "Ironwood" or "Water Beech." It grows especially well in moist situations and endures a great deal of shade. When standing in the open this tree usually develops a very low round head upon a short trunk, which is sometimes curiously twisted or ridged, suggesting straining sinews and muscles. The bark is smooth and of a bluish gray. It has handsome foliage, but its most characteristic feature is the long spray of fruit, each fruit being protected by a much enlarged leaf-like bract. Its autumn color of orange and scarlet is very fine.

Dogwood.

The spring glory of our eastern forests is the "Dogwood," a beautifully shaped tree of small size. When covered with the masses of flowers, it surpasses anything in our woods (see Plate 10, Fig. 1). The flowers themselves are small, pale green, and rather inconspicuous, but the bracts, which in the winter fold over the flowers, and in the spring expand into large petal-like leaves, are very showy. The small scars on the ends of the bracts are caused by the exposure these tips have to bear all winter long while protecting the real flowers. Occasionally a pink variety is found, and these have been propagated for horticultural purposes.

American Chestnut.

This is a tree of much, but rather mournful, interest. Though useful as a lumber and fruit tree, handsome in summer and winter, and even now one of the most frequent trees in many sections of the east, it seems doomed to destruction—to be wiped off the face of the earth, so look at it closely the next time you see it and enjoy its beauties while you may. Only five years ago a parasitic fungus was first noticed to be preying upon this tree in a very small section right here in New York City, and it was then predicted that in ten years no chestnuts would be left alive upon this continent, unless something happened at once to check the progress of this disease. This prediction caused much shrugging of shoulders and amusement, among the talent, but unfortunately even the most sceptical are now convinced. The tree reaches a height of 100 ft., with a round top that often reaches its height in spread, and its rough barked dark gray trunk ten or more feet in diameter. The flowers of the Chestnut are clearly shown in Plate 9, Fig. 1, which contains both the pistillate and the staminate. They are borne in great abundance in July. We can see here, how on trees of this kind, which depend largely upon the wind for carrying the pollen of the male flowers to the stigma of the female one, the staminate flowers predominate, in order to supply untold millions of little pollen grains which fly about in the air, and of which only an occasional one finds its way to the pistillate flower and fulfills its mission of fecundation. The very handsome foliage is dark green, glossy, and regularly veined; it turns bright yellow in the fall. The fruit is enclosed in and protected by a spiny burr, rough and forbidding outside, but lined with the silkiest smooth white velvet (see Plate 9, Fig. 2). This burr is opened by the early frosts of autumn, allowing the nuts to fall upon the ground, where those that escape the squirrel and the small and adult boys, germinate the following spring. The wood of the Chestnut is rather coarse, but very durable; it is used extensively for fence and telegraph posts, railroad ties, furniture, and interior trim. It will be very hard to get along without it. A cross-section is shown in Plate 11, Fig. 2.

Black Walnut.

The Black Walnut makes a beautiful round topped tree of large size, and was formerly found in large forests, especially in the basin

PLATE 9.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MERKEL ON SOME INTERESTING
AMERICAN TREES.

Fig. 1.—Chestnut Blossoms. Staminate and Pistillate.

Fig. 2.—Chestnut Burrs. Chestnut Trees are Rapidly Disappearing on Account of the Bark Disease.

PLATE 10.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MERKEL ON SOME INTERESTING
AMERICAN TREES.

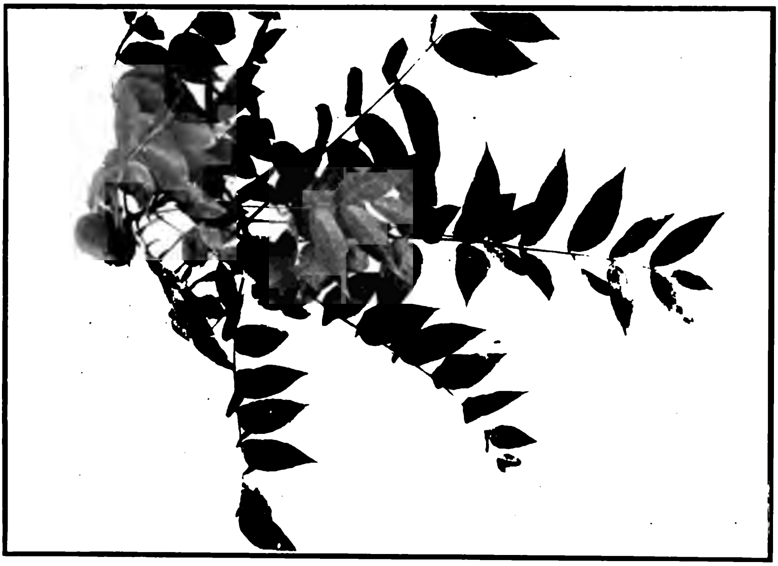

Fig. 2.—Black Walnut. Good Trees Are Now Very Rare.

Fig. 1.– Dogwood. the Glory of Our Spring

of the Mississippi. It grows or rather grew, from Massachusetts to Louisiana, and westward to Nebraska, in large quantities, but was rapidly used up because it seemed to the early builders an ideal wood for railroad ties, not so hard as white oak, but just as lasting. Just about the time that the last lot of Black Walnut was cut up for ties, the fashion in furniture turned toward it, and the lumbermen were glad enough to pull up the stumps of the fine trees they had cut down and make furniture out of them. The Black Walnut is, however, a tree that is easily grown, and there is no danger of its extinction. The foliage is very handsome, dark green, and aromatic. The large edible fruit was an important article of food with the Indians (see Plate 10, Fig. 2). The wood is of fine grain, a rich dark brown color, very durable and easily worked. It weighs about 39 lb. to the cubic foot. It is used for interior finish of buildings, gunstocks, and furniture, and commands a high price.

CATALPA.

The Catalpa, or Smoke Bean tree, is the one native tree of which it may be said that it is more numerous now than before the country was settled, though in smaller specimens. Originally growing in only a small section of the central states, it has now been planted in large trial forests by many railroads and other wood consuming corporations, as well as by private owners, it being the fastest growing tree that produces valuable lumber. Its foliage is large, heart shaped, and light green, and the large trusses of beautiful flowers make it conspicuous and desirable for park planting (see Plate 13). The seeds are carried in long slender pods. Its wood is light, weighing 26 lb. to the cubic foot, and is very durable in contact with the soil, for which reason it is good for cross ties, telegraph poles, and fence posts. Its handsome grain also recommends it for furniture, etc.

WILD CHERRY.

The Wild Cherry is a tree which deserves more popularity than it has. It makes an open, round-headed tree, very vigorous when young, but of slower growth when older. The bark flakes into many scaly plates, and is very characteristic. The leaves are dark green, smooth, and glossy, on bright days reflecting the sunlight in a way that is most dazzling to the eye. The flowers are white and small,

but borne in immense numbers, and add greatly to the many attractions. The fruit is a small purplish drupe with a single seed encased in a hard shell. The wood is of very fine grain, hard and strong. It weighs 36¼ lb. to the cubic foot, and is, on account of its beautiful reddish color and satiny sheen, very much prized for cabinet work, interior finish, furniture, etc. Much "real mahogany" furniture has its origin in this tree. The whole tree contains a large amount of hydrocyanic acid; so much that the wilting leaves have been known to seriously poison domestic animals that have eaten them. An important drug, useful as a tonic, is made from the bark.

Red Cedar.

The Red Cedar, which is really not a Cedar, but a Juniper, is a tree of wide distribution, growing from Nova Scotia to Florida and westward to Ontario and South Dakota. It is very hardy, growing on the most exposed ridges in poor and rocky soil, though in such situations it grows very slowly. The trunk is usually straight and covered with thin reddish bark, the outer layers of which peel off in long strips, and are much used by squirrels and birds for lining their nests. The leaves are really nothing more than small stemless scales lying close to the twig, and persisting for three or four years. The fruit is a small blueberry-like cone, and with the leaves, is used in medicine. Spirits distilled through them makes the gin of commerce. The wood is reddish, close grained and soft, very aromatic, and much used for the building of coffins, clothes chests and the like, and when of straight grain and free from knots, it is used in the manufacturing of pencils. Another use of the Red Cedar is for ornamental purposes, rivalling certain types of the famous cypresses of Italy, which unfortunately are not hardy here.

Pine.

The White Pine is distributed over a large area reaching from Newfoundland to Manitoba, south to northern Georgia, and east to the Atlantic coast. What the White Oak is among hardwoods, the White Pine is among conifers. Stately, rugged, and picturesque in outline, spreading over a great area when standing alone, this tree reaches a height of 150 ft., and commands our attention wherever seen, and like the White Oak, it is as useful as it is attractive.

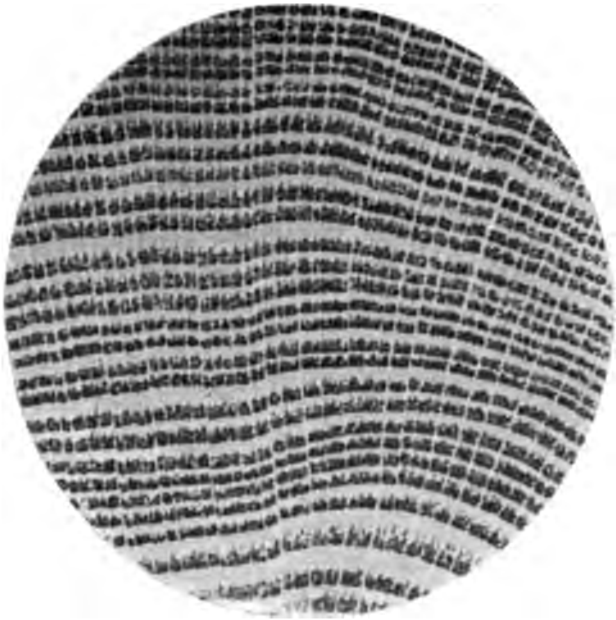

FIG. 1.—SECTION OF RED OAK, SHOWING CLEARLY THE PROMINENT PITH RAYS WHICH MAKE THE SILVER GRAIN WHEN THE WOOD IS QUARTER SAWED.

FIG. 2.—SECTION OF CHESTNUT, COARSE, STRONG AND DURABLE IN CONTACT WITH THE SOIL.

The foliage is composed of fine soft needles of a silvery green, carried in bunches of five, and is the only eastern Pine which has that number of leaves in one bundle, so it may be easily identified.

The flowers are of two kinds, small and inconspicuous. The seeds are contained in long cones, the scales of which open and close according to the weather, allowing the small naked, but winged seeds to escape when the sun is shining, so that they may be carried to a distance and plant new groves (see Plate 12, Fig. 2). The wood is soft and easily workable; it shrinks and checks but little and was at one time the most important lumber of the country. Even in the short space of time covered by my memory, White Pine lumber has increased in cost over 100%, and is now so scarce that other woods are largely used in its place. How destructive the lumbering carried on by us has been, is fully proved by this one tree. Formerly great forests of Pine were found in New York and Pennsylvania. When they were used up, Maine became the principal lumbering state, until it was denuded. Westward to Michigan the Pine was pursued and overcome, and only small and scattered areas are left anywhere. Where formerly the East shipped White Pine lumber to the West and South, we must now buy Cypress and Yellow Pine from the South, and Oregon cedar from the West, to take as well as it can the place of White Pine. Yet here is a tree which we may hope to see again on our hills and mountain sides, for it grows well and quickly, even in burnt-over lands.

A western representative of this genus is the Bull Pine, which grows throughout the Rockies from British Columbia to Texas, frequenting higher and higher altitudes as it goes southward. It is, for a Pine, a remarkably slender tree in outline, reaching a height of over 200 ft. and a trunk diameter of 6 to 8 ft. Comparing the spire-like tree of the forest and the sheltered plateau with the wind-torn scrubby one in exposed positions, and the almost creeping shrub from near the timber line, where the weight of feet of snow and the icy blasts of wind have driven the trunk to lie flat upon the ground, one can hardly believe them to be of the same species, and must marvel at the endurance and hardihood of this tree. The wood is the principal building lumber of the West.

The most important Pine of the South is the Yellow Pine, or long-leaved Pine, with a tall slender trunk from 100 to 120 ft. high.

The leaves of this Pine are the longest of any, often being from 12 to 18 in. long. They are much used for Christmas decorations. The wood of this tree, called yellow pine, is very resinous, heavy, and strong. It lasts well in contact with the soil, is very useful for piles in dock and bridge building, for interior finish, and for masts and spars of vessels. The demand is immense and the supply is yearly diminishing. When in the course of time all the timber that is easily lumbered shall have been used up, we will no doubt have to go to the Rocky Mountains for wood, as we have already done for ornamental trees.

SPRUCE.

One of the handsomest of all the evergreens is the Blue Spruce (see Plate 15). It comes from Colorado, and is much planted in fine gardens, being very hardy. The very blue ones are garden varieties grafted upon the greener seedlings, and sell at high prices, though judging from the older specimens in cultivation, they are likely to lose their symmetry which is a great asset to them when they attain large size. The wood is weak, light, and of fine grain.

Another very handsome Spruce from the Rockies, is Engleman's Spruce, which is also used a great deal in horticulture. In the Canadian Rockies this tree reaches a height of from 100 to 150 ft. Its wood is very useful as building lumber and it also makes good charcoal and fuel. A section of this wood is shown in Plate 14, Fig 1.

The most useful of the Rocky Mountain Spruces is the Douglas Fir, an immense tree from 150 to 200 ft. high, found growing upon the Rockies from Alaska to Mexico (see Plate 16). It is one of the largest of our trees, has handsome bright green foliage and drooping branches. For heavy timbers in ships, wharfs, and bridges, and for masts, this tree is very valuable, as its wood is strong, hard, and tough, and can be had in sticks of great size. For boards it is not good, being too hard and warping too easily.

BIG TREES.

Probably the oldest living things on earth to-day are the Big Trees of California, Sequoia Washingtonia. About 325 ft. high, with a diameter of 35 ft., the Big Tree towers above the handiwork of mere man, silently, and with little change to itself, letting the

PLATE 12.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MERKEL ON SOME INTERESTING
AMERICAN TREES.

FIG. 2.—WHITE PINE CONES AND LEAVES.

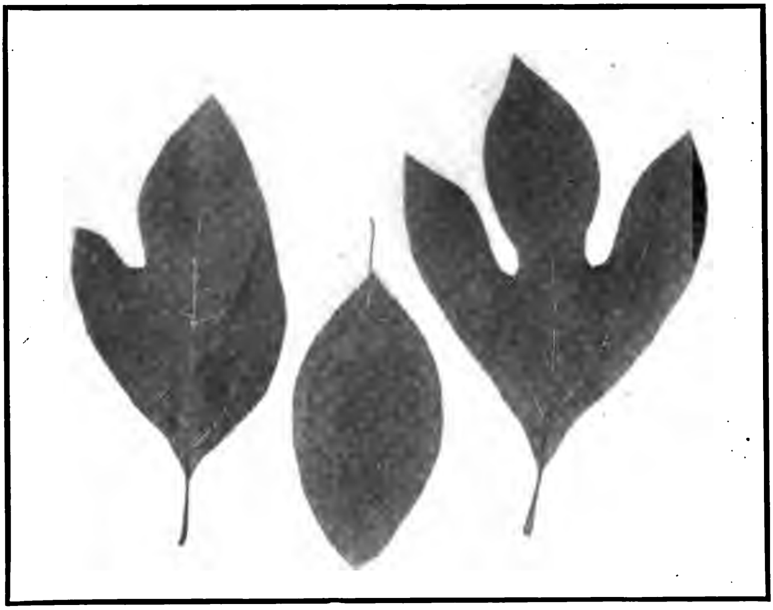

FIG. 1.—VARIOUS FORMS OF SASSAFRAS LEAVES.

centuries slip by as we do years; 4 000 years is the estimate of the age of the largest standing tree, which means that it was a giant when Christ walked this earth, and already a lusty youngster of a thousand years or so when Troy fell at the hands of the Greeks. It is found only in a small portion of California, in a half-dozen groves, one of which is now owned by the United States, thus insuring the preservation of at least a few of these giants. Seedlings of these trees do not do well here in the East, but in various parts of Europe they have succeeded. The wood of the Big Tree is coarse, weak, and brittle, and is bright red and very durable in contact with the soil. A single tree has yielded 537 000 ft. of lumber, yet in spite of this lumbering of these trees is said not to be very profitable because of the enormous waste entailed in blasting the logs, which, of course, are too big for any saw-mill to handle. Strange to say, the cones of these trees are not as large as those of our White Pine, and the seeds are only $\frac{1}{8}$ or $\frac{1}{4}$ in. long.

Redwood.

Nearly as high as the Big Trees, but of much smaller diameter, is the Redwood, Sequoia sempervirens, which is found in company with the Big Tree, though covering a wider range. The maximum height appears to be about 300 ft., with a diameter of 30 ft. Its wood is red, soft, easy to work, takes a high polish and is highly prized for many uses. A section of this wood is shown in Plate 14, Fig. 2. The forests of Redwood and Big Trees are said to be the most awe-inspiring sights on earth. Let us hope that we can forever preserve these two relics of a prehistoric age.

Monterey Cypress.

Fighting like a battle-tried veteran against an overwhelming force, clinging with wide-spread roots to the almost bare rock, defying time, wind, and sea, stands the Monterey Cypress. These trees grow right upon the edge of the land, with the waves beating against their very foundations, and are found only on a small strip of land around the Bay of Monterey. With their short, thick trunks, contorted spreading limbs, and their flat tops, they excel in picturesqueness and beauty. Some of the larger trees are of very great age, probably 1 000 years or more. The old trees all seem

doomed, for the waves are gradually wearing away the crumbling rocks upon which they grow. Fortunately for the species, however, it grows well in cultivation, and is planted as an ornament along the Pacific Coast and in Europe. There are several garden varieties.

SPINY SMOKE-TREE.

The Spiny Smoke-Tree shows how the vegetation of a country adapts itself to the conditions of climate and soil. This tree grows in the desert lands of Arizona and Southern Mexico. It has but few leaves and they are so small as to present little surface to the sun, and so placed at the base of the very numerous spiny branches, that they are to a large extent shaded by them. The trunk is short, branching soon after leaving the ground. The wood is coarse, soft, and brown.

OCATILLA.

An even more striking desert tree is the Ocatilla or Devil's Chair. Its apparent architecture is entirely shrub-like, but in realty it is a tree. Its trunk, however, is usally buried in the sand, so that only its long rod-like branches appear above the ground. The small leaves of this tree grow all along the branches, though they are 18 ft. long, and when the tree is done with them, or they fail for want of moisture, these leaves do not fall off entire, but loosen in two pieces along the midrib, which remains and becomes a full-fledged thorn. When it happens to rain again, which is not often, a new lot of fleshy leaves spring from the branches, only to add another consignment of thorns when their time comes to die. No wonder that the Ocatilla is not a pleasant thing to handle.

CACTUS.

Of great interest also is the Saguaro (pronounced Sa-wa-ro), or Giant Cactus, a marvel among plants. Reaching a height of 50 ft. or more, with few branches, as massive as the trunk, and not tapering at the top, it is purely a product of the desert. A quantity of soil so small that any self-respecting hill of beans would refuse to live in it, and a little bit of water once in a great while, seem all-sufficient for this monster to rear its great candelabra-like bulk. Its trunk is curiously constructed in so far that the sustaining wood is found on the outside in many rod-like pieces, and the center where this dead wood should be, is soft and pulpy. The roots of this

PLATE 13.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MERKEL ON SOME INTERESTING
AMERICAN TREES.

THE CATALPA, A VALUABLE ORNAMENTAL TREE.

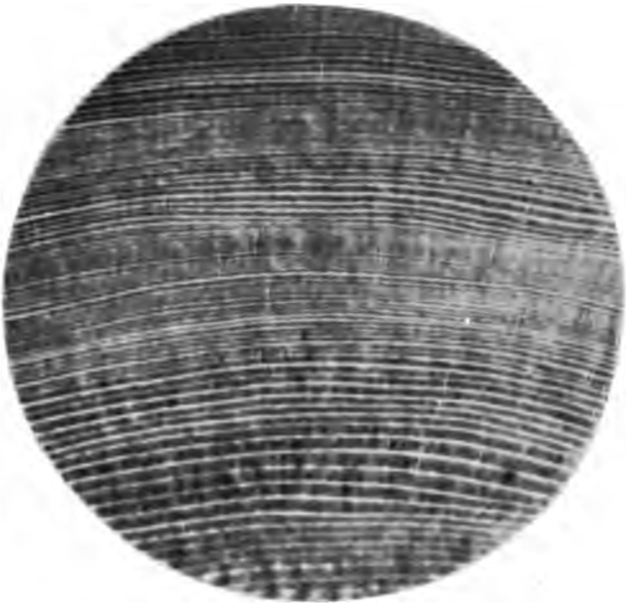

FIG. 1.—SECTION OF ENGLEMAN'S SPRUCE, A VERY FINE GRAINED WOOD, LIGHT IN COLOR AND WEIGHT, AND USEFUL FOR MANY PURPOSES.

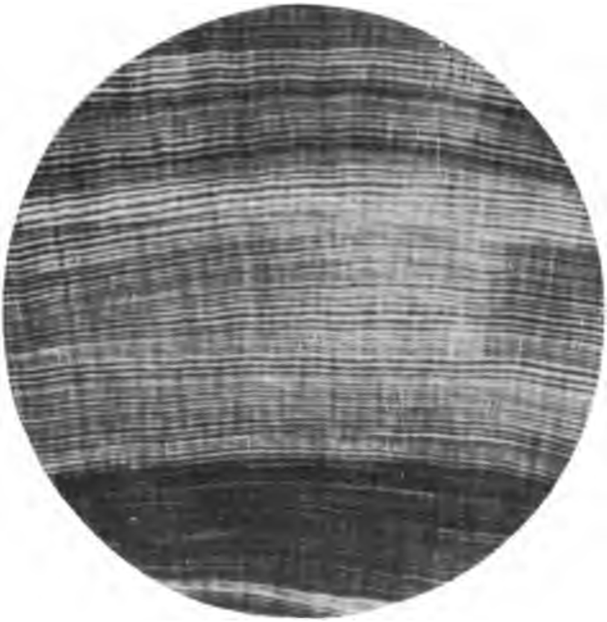

FIG. 2.—SECTION OF REDWOOD, NATURAL SIZE. IT TOOK 139 YEARS TO GROW THIS PIECE OF WOOD.

tree spread in all directions for a great distance, and lie very near the surface, so that they are able to absorb great quantities of water. The main stem as well as the branches are plaited like an accordeon and they can swell and shrink, according to the amount of water they contain, without splitting the skin. The flowers are white and very attractive. Dr. Hornaday, the Director of the Zoological Park, who recently went through the great Sonora Desert on a trip of exploration, says that the woodpeckers love to burrow in its soft cool pulp, to make their nests, and it seems that a safer or more secure nesting place could not possibly be imagined, since no marauder (mammal or reptile) would brave the perils of the formidable row of spikes with which this plant is armored.

A cactus more shrub-like in form, yet tree-like in proportion, is the Organ Pipe Cactus, which rears its many branches, 8 to 10 in. thick, to a height of 20 ft. The fruit of this cactus is of great importance to the Indians of this region.

While on the subject of cacti, I wish to mention one that is sometimes of great value to the desert traveler; that is the Barrel Cactus, or Bisnaga (Echinocactus wizlizeni). This plant stores up in its soft pulpy pith, quite a quantity of water, which the traveler may obtain by pounding and pressing the pulp after the top has been removed. Undoubtedly this store of water has saved the life of many a traveler through this arid country.

Honey-Pod Mesquite.

The only lumber tree of this desert (if the name lumber may be applied to the crooked sticks it supplies), is the Honey-Pod Mesquite, and it is also useful in other ways. This tree grows to a height of about 45 ft., has a short thick trunk and many twisted and crooked limbs. Its bark is dark brown, rough, and scaly. The leaves are twice pinnate and the leaflets are very small, but useful as forage. The fruit is a long pod filled with small round beans, which are used as fodder for horses, and occasionally eaten by man. The wood is hard and durable and being the only wood available, is the best there is for fence building, furniture, and to hold up the earth roofs of the desert dwellers. It also makes good fuel. The one great enemy of this tree seems to be the Mistletoe, a parasite that fastens upon it, and sometimes appears in so great numbers as to kill it.

JOSHUA TREE.

A tree different from any we have seen so far is the Joshua Tree, or Tree Yucca, which with its angular branches and leaves tufted upon their ends, makes a striking picture. It is found in the deserts of California, Utah, and Arizona. Its greatest height is between 30 and 40 ft., with a trunk diameter of 2 ft. The leaves are about 10 in. long and taper to a very sharp stiff point. The white flowers come in dense panicles, and are followed by the round seed pods, packed with 3 rows of flat seeds, which are ground and eaten by the Indians of that region.

PALM.

The Washington Palm, Neowashingtonia robusta, is found in Southern California, where it reaches a height of about 75 ft., with a trunk diameter of from 2 to 3 ft. The fan-shaped leaves are large, sometimes 6 ft. across, and are deeply cut into fine long points. The dead leaves drop downward and, overlapping one another in a layer several feet thick, remain hanging a long time.

A very similar palm is the Sabal Palmetto, or Cabbage Palmetto of Florida, Georgia, etc., where it is at home in the coastal regions. It grows to be about 40 ft. high in Florida, getting smaller further north. The leaves are much smaller than those of the preceding species, and break off at a point about 3 or 4 in. distant from the trunk, instead of remaining on, like the Washington Palm. The bud at the top of the trunk of this species is used for food, and hence the name, Cabbage Palmetto. Of course, removing this bud kills the tree. The leaves are used for thatching houses, and hats and baskets are woven from them. The Palmetto is much used for ornamental purposes in the South, as it grows very easily. When a large plant is to be shipped any distance, the leaves and roots are all cut off, and the trunk is shipped much like a log of wood. When planted it soon puts forth new roots and leaves.

The Cocoanut Palm is probably distributed over a larger area than any other tree known. Though probably of American origin, it is found in all parts of the Tropics near the sea coast. It is also one of the most useful palms known. In its favorite locations and soils the Cocoanut Palm becomes 100 ft. high (though generally much smaller), with a trunk diameter of 1 to 2 ft. The graceful feathered

Colorado Blue Spruce, One of Our Native Trees, Much Used for Ornamental Purposes.

DOUGLASS SPRUCE, A VALUABLE LUMBER TREE.

leaves are very long, 12 to 18 ft., and, waving in the breeze, present a beautiful spectacle. The fruit is very abundant and large, and consists of a thick, light, fibrous husk, mixed with pith, enclosing the hard shell, which is lined with a thick white layer of meat or albumen. The construction of the nut very probably accounts for the wide distribution. Living, as the Palm does, upon the edges of creeks and bays, some cocoanuts will fall into the water, and being hollow, and made still lighter by the outer soft and fibrous husk, they will float and be driven about by the sea currents and wind until they perish or are thrown on the land by the waves. The inner bony shell is impervious to water, the husk acts as a buffer, and the germ is well protected to float about for months. Once safely landed, the heat of the sun soon causes the nut to sprout and make root, and the young tree is established. The uses of the cocoanut are many; the fibres of the husks are used for ropes and mats; the fresh meat and milk are good wholesome food and drink. The dried meat, called copra, is an important article of commerce, yielding the well-known cocoanut oil, which is used for food, soap-making, and in the drug trade.

MANGROVE.

A tree of most interesting habits is the Mangrove (Rhizophora Mangle). Its favorite location is in the marshes, tidal lands, and along the bays and rivers of southern Florida. In such places it makes a round or flat topped tree 60 ft. high, whose individualism, however, is soon lost through the fact that it throws out aerial roots, which, branching out toward the bottom, soon become new trees, though still connected with the parent stem, thus forming impenetrable thickets that gather refuse and silt washed in by the tide, and ever reaching further into the water, soon transform the coast-line. Added to this prolific branching habit is the curious fact that the seeds sprout and make root before they drop off the tree into the mud, where they quickly make trees.

The Banyan Tree, which is the ordinary rubber tree of the florists, has the same rooting habits. Though an Asiatic species, it is rapidly becoming established in southern Florida.

DISCUSSION.

MR. ROBERT R. CROWELL.—Gentlemen: We have listened with a great deal of pleasure to the author of the paper of this evening which has been very interesting. It is very seldom we have the opportunity to travel from Florida to the northern part of America, and from the Atlantic to the Pacific Ocean in one evening. Probably some of you gentlemen would like to ask Mr. Merkel a few questions. If so, I know he will be pleased to answer them.

MR. ERNEST L. MANDEL.—If I remember rightly, I read somewhere that Mr. Burbank, of California, made some experiments with a spineless cactus. I should like to know the difference between the spineless variety and that spoken of by Mr. Merkel.

MR. HERMAN W. MERKEL.—In the opinion of the newspaper and magazine reading public Mr. Burbank is one person, and in the opinion of eastern horticulturists, another. The newspapers have given him a great deal of notoriety and have made him out a wizard and a creator of new things, yet I have seen it stated as a fact in the horticultural press, that the plum which made Burbank's name was imported from Japan, and did not originate with him. One experience I had with Burbank seems to point rather to the opinion of the horticulturists. The firm by whom I was then employed purchased a white blackberry, which according to his description was to be as large as one's thumb, pure white, and a well-flavored fruit. We propagated about ten thousand or more for distribution, and when they came into fruit they were dirty, seedy little things that no one would eat, much less buy.

As to the spineless cactus, they existed probably a few thousand years before Burbank was thought of. Mr. Burbank has taken some of these, and by selection and possibly by cross-breeding, but probably merely by selection, has "created" a spineless cactus which was to make the desert bloom like Paradise and make thousands of acres of arid desert land useful for stock raising. This was some years ago but no one is raising stock in the desert. I have never seen them, but I have been told by people that have, that these cacti have indeed no long spines, but have bundles of minute hairs, very sharp and needle-like. These would so irritate the throat of any animal that the beast would soon die. I have myself gotten cactus hairs into my fingers, and know how it must feel to an animal to get them into its throat. It is almost impossible to get the needles out without breaking them, and they simply have to fester or wear out. From this I do not believe that Burbank has a spineless cactus of economic value. There are people who have done a great deal more for horticulture and agriculture than Burbank, but they have not been able to get the advertising, especially the free advertising, that Burbank has. To my mind people like Vilmorin, Spath, Damman, and Downing, have done more than Burbank, but it is almost dangerous to say so.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 48.

PRESENTED APRIL 28TH, 1909.

IMPROVEMENTS OF THE APPEARANCE OF MUNICIPALITIES.

BY CHARLES W. LEAVITT, JR.*

WITH DISCUSSION BY
ROBERT R. CROWELL, ALFRED D. FLINN, MAX L. BLUM
AND CHARLES W. LEAVITT, JR.

The very rapid growth of the cities in America, and in the United States in particular, has been such that the adornment of them has, for several reasons, been neglected.

In the first place, the improvements in American cities have been of a more or less temporary character, and any money spent purely for æsthetic effect has frequently been wasted on account of the necessity of tearing up and rebuilding streets to provide for the various pipes, conduits, subways and pavements, made necessary by the increased requirements of the people, and also for the extraordinarily heavy travel which in many places passes over our streets. These practical provisions for the wants of the people have not been the only cause of the lack of embellishment. Many buildings which were erected only a few years ago have been replaced rapidly by other structures with more modern improvements. In many cases, good, substantial buildings have been torn down to make room for higher or more commodious structures. Furthermore, the requirements for the actual needs of the people have been such that most of the

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NOTE.—When this paper was presented before the Society it was accompanied by many beautiful and instructive lantern slides. These illustrations were unfortunately unavailable for reproduction, as their owner took them to Europe and did not return until after this publication was printed.—ED.

available funds of our municipalities have been used up for necessities, and little or no money for the beatutiful has been left available.

A still further reason for this lack of artistic embellishment is that very few of our municipal engineers have been educated along the lines we are now discussing. Their education from a standpoint of the engineer as it is commonly recognized may have been perfect, but they have not been taught the laws of proportion, color and general treatment to gratify the eye, as the university faculty has not deemed this necessary. In very recent years the lack of this artistic element has been noticed by people who have traveled abroad and seen the streets and parks of cities where there has been sufficient means to carry out the work of improving the appearance of the city, and where the people have been educated to want these improvements.

Unfortunately, the engineer, and especially the municipal engineer, is not only busy with his work, but is frequently tied down so that it is difficult for him to get away for periods of sufficient length of time to enable him to travel abroad, and very frequently his means do not permit of this. We, therefore, have the condition of affairs existing, of very little desire on the part of the majority of the people for these artistic improvements, and the few who do wish them are discouraged by finding that those in charge of affairs do not thoroughly appreciate their wants, and if they did, would not have the power to obtain the means to carry them out.

As our cities become more established, and the architecture of the buildings fixed, and the means of the city such that a surplus of money becomes available for adornment, we shall be ready to go on with these improvements and they will be demanded by the people, as the more one is educated, the more desire is developed for art and for having things orderly and beautiful. It would, therefore, seem that there will surely be a demand upon the municipal engineer to understand these things and he will be confronted with the problem of obtaining this information, and in order to occupy prominent positions he will have to know this subject just as he understands other subjects covered by the usual professional training. When this is realized, there will be a demand for this information, and it will be somewhat difficult to supply the demand.

If our engineers could all travel abroad frequently, such studies

would help materially, but this is impracticable. If we had in every one of our colleges, professors who thoroughly understood these requirements, it would help. If we had a few trained men who understood this subject, and who were public speakers, and could circulate this information, it would be a great source of education. If our authors would devote some of their time to this important subject and produce books containing this information, I think they would be eagerly read, not only by the municipal engineer, but by all those who are interested in the improvement of our general surroundings. Illustrations of the various forms of embellishments used are one of the greatest helps which any one can have in studying this subject.

I find that one of the best means of obtaining illustrations of such subjects in which I am interested is the picture postal card with which we have become so familiar, and which, I believe, will be the medium for conveying much artistic information. If those who are interested in this subject would ask their friends who are traveling abroad to collect for them postal cards illustrative of subjects concerning which they are most desirous of informing themselves, such as street signs, street pavements, general condition of the streets and adjacent buildings, fountains, statues, etc., they would soon collect much valuable information. Another way would be to obtain books illustrative of foreign cities where such improvements have been made, and some of our home cities, which I think are just as fine as anything abroad, only there are not so many examples. It might be well also to suggest to your sons or friends who are now at college, to make a demand upon the college or university, to have some lectures on this subject, possibly a course of study, as this knowledge will undoubtedly become a valuable asset in a few years.

I have perhaps elaborated somewhat upon the demand and supply of this subject, as it seems to me it is the root of the matter, and if we can find out just what the demand or necessity is, and what is the available supply, and how to help that supply along, we have accomplished something.

To be more specific in regard to the general municipal improvement of cities, I should sum them up under several headings:

Service Pipes and Their Attendant Adjuncts.

In planning city streets, very great thought and care should be

given to the location of the service pipes, so that, if possible, connections can be made without tearing up the street pavements. This is a difficult thing to arrange, as it is almost impossible to foresee what the development along the line of any street will be.

In planning some city streets recently, I arranged to put in service connections as far as the lot lines, endeavoring to plan this as nearly as possible to meet the improvement expected. While in some cases this arrangement will not work, yet it will probably save tearing up the streets many times, as undoubtedly some of these connections can be utilized to advantage. Every time a street pavement is torn up, a bad hole is liable to develop in the pavement, and nothing is more unsightly than an uneven, broken pavement, and from a standpoint of appearance, it is a bad influence for the whole community, and is most disagreeable to travel over.

In planning these service pipes, they should be made so large that, if possible, they will supply the necessary service until they are worn out. Of course, this cannot always be arranged, as sometimes cities grow very rapidly, but the tendency has been to make the pipes too small, and it is necessary to replace them long before they are worn out, and thus good material is thrown away and the streets torn up, and when one considers what a large part of the cost of putting in service pipes is the ditching and the replacing of pavement, we readily see that the use of pipes so small that they may be outgrown before they wear out is false economy.

Subways and Tunnels.

In some European cities, subways and tunnels have been provided to take care of these service pipes, and this is most advantageous, as it avoids tearing up streets for repairs, connections, or replacements, and leaves the pavement undisturbed.

Of course, it is not practicable to build subways and tunnels in new communities, as the cost would be prohibitive, but where renewals are contemplated in old city streets, thought should be given to arranging for such permanent places for the service pipes, as frequently it is much more practical than the continuous digging up which goes on in most of our cities. This is especially true with cities where subways for the use of travel are practical, and, undoubtedly, arrangements could be made to have pipe galleries in

connection with the portion arranged for cars, and thus one tunnel might answer for every purpose.

Street Signs and Street Lighting.

Street signs and street lighting are perhaps the most important matters to be considered in connection with general street appearance, as of necessity we are bound to use many lamp-posts of one kind or another in city streets, and the signs for direction, and bulletin boards are essential.

I have been much interested in the way this matter is handled in some cities, particularly the bulletin boards. I found some built in the form of small towers of artistic design, and located on prominent corners. On these built-up posts, which are several feet in diameter, are pasted the theatre notices, notices of various meetings, and anything of particular public interest. They are decorative and interesting to look upon. These sign boards are frequently surmounted by electroliers or some lighting device, which not only sheds light on the street, but upon the posters themselves, so that one can read them at night, and even from a carriage or car window in passing.

The general lighting support has been designed in so many different ways that it is almost too great a subject for practical discussion at this time, but a few essential points might be brought out. In obtaining the greatest efficiency from electric or other lights, one finds that as far as possible ground or colored glass should be done away with, as it affects the efficiency of the light. Furthermore, the supports which hold the lights are inclined to give dense black shadows on the pavement, which are disagreeable, and at times dangerous. The old-fashioned "goose neck" hanger, which is so frequently used, is not a very ornate affair, and while the post may be made very beautiful, yet its top falling away in a weak curved line is not agreeable. I have endeavored to work out this problem in one location, and have arranged for a post that would obviate some of these difficulties, as well as provide street signs for direction. I have found that a lamp supported by three arms, one of which would throw a shadow up the curb, one down the curb, and one directly across the pavement, would obviate the shadow difficulty very materially; then by eliminating any glass except the globe for a

"Tungsten" light, and so arranging the reflector that light would be thrown up and through some glass signs, a very simple and effective light would be obtained.

The many designs which have been utilized with two bar supports, one throwing a shadow up the curb and the other down, have been a great advancement along this line, but they are not altogether satisfactory from an architectural standpoint, and I think much could be done still to improve the street lamp-post and lamp. I am rather partial to the old bracket lamps which one sees in the older streets in some cities in Europe. While these might be used to some extent in our more densely populated cities, they would be impractical for suburban sections or points where the streets were not so generally built up.

The Effect of the General Architecture of the City.

This is so important an item that great space should be given to it, as, after all, the general effect which is produced upon one is by the architecture of the buildings, though, I think, as time goes on, the impression received from the streets themselves will have almost as great an influence.

Our cities were first started by people who needed houses to live in, and places in which to transact their business, with little means to spend on ornamentation, and, therefore, the first products of this country were in many cases not of the best; though in looking over old prints of the first houses in New York, I must say that they give one a more pleasant impression than the buildings of to-day, but I feel inclined to doubt if some of these old prints are true, and think that perhaps the town did not look as well in reality as the pictures would lead one to believe. Furthermore, their problems were not as severe as ours are to-day. The tendency towards building enormously tall structures in very narrow streets has given us a problem which is very difficult to solve.

The municipal engineer will undoubtedly have more and more to do with these buildings, and he should make it his business to endeavor to bring about as much simple ornamentation as possible on the street fronts of these buildings, and to have them arranged so as to provide the greatest amount of light and air, and for the utilizing of the roofs for recreation spaces, as to-day we have acres

of roofs which might be used by the people in their spare moments for recreation, and in the summer for breathing spaces. As yet there is no provision made for this.

The building materials which the architects of to-day use are perhaps as much under the eye of the municipal engineer as the architect, and I think it right and proper that the municipal engineer should only sanction such materials as will withstand our climate, and develop architecture which will be pleasing to the eye, as well as durable for the structure.

Public Squares and Their Relationship to the Streets.

It would be well if each community could have a civic center, a square or mall on which the Municipal Buildings, etc., could be built—the old New England idea of a village green.

The public square and its relationship to the street and to the city as a whole is most important. We have far too few such open spaces in our cities, and in European cities they are almost as sadly in need of them as we are. These open spaces are valuable from a purely monetary standpoint, as all properties fronting on such open spaces have greater value than those on small streets. Whether these spaces be wide boulevards or open squares, the property thus given up would be more than paid for by the increased value of the adjacent land. Further, in the event of a large city fire, these open spaces give place for the firemen to operate, and form fire lanes where such conflagrations can be arrested. It is difficult to obtain such spaces in cities which have already been built up, but in new towns these openings should be planned for, and more of them provided than appear necessary.

In the development of these city squares, more thought should be given to providing for large congregations of densely massed people rather than for natural and rural effect. For instance, if turf is practically done away with, and the area planted with shade trees which will grow up and form a canopy as a protection against the sun, and the ground beneath covered with sand or gravel, in which the children may play, and which will form a dry footing for those seeking exercise, we could obtain a result far more practical than the ordinary turf square with asphalt walks. The square is hardly the place for much turf. The square should be more of a

common, and perhaps fenced in, with certain definite openings left, which would restrict the cross travel, and such railings would afford corners and places where games could be carried on, and people could walk without being disturbed by those in a hurry. The development of these play-grounds or public squares has not been thorough in this country, and only in a few places in Europe, but I think one will readily see that the foregoing is a more logical solution than trying to form minature parks of these squares in congested districts.

PARKS.

Parks are undoubtedly the greatest asset that a city has, as upon them depends the health and sanity of the people, and I think we will all admit that a large city population would eventually deteriorate, if it were not for these breathing spaces and room for proper exercise amid nature.

The creation of these parks is largely in the hands of the municipal engineer, as in his work the subject of parks is bound to come up in one way or another, and if he is an enthusiast on this subject, he can frequently guide those in power in such a way that parks and pleasure grounds will be created where they do not exist, and those improved which are available, but have not been developed. This is a popular subject at the present time, and a municipal engineer will find that if he upholds attempts to advance a park project, he will have behind him the public, as the adults are on the watch for conditions beneficial to themselves and their children, and the children themselves are anxious for proper play-grounds.

The engineer, and the municipal engineer in particular, is of necessity forced more and more into the business end of large undertakings, and it would seem that it was to some extent possible for him to improve the business methods by which such work is carried on. The education of the engineer is of necessity always on the lines of strict honesty and integrity, as not only his technical figuring and subsequent work depend absolutely upon honest calculations, but he is also called upon to act in a judicial capacity between the municipality or owner and the contractor. In order to put through the large municipal problems which are planned, he must come in contact with those in command of the business of the city. Mr. J. A. Bensell suggested to me that the engineer should be trained

in political economy and the study of human nature, as the success of an engineer depends in a large measure upon his capacity for handling his clients and so conducting his work that he may be fully supported by those in power. There is no reason why such action should in any way affect the professional standing or etiquette of the engineer, as his great strength is really dependent upon his professional record.

Some private enterprises, such as a few of the large railroads, are very largely governed and operated by men who have been educated as engineers, and most of these companies so officered are successful. For instance, the Pennsylvania R. R. Co. is operated largely by men from the engineer corps, and there is no other such railroad organization in the world. Why not have our cities governed and directed by men taken from the engineer corps? These men are familiar with all the intricate construction details of the city, and know the requirements of the people and how to obtain what is desired. This would seem logical, but it remains for the engineer to receive the proper training in the study of mankind in addition to his technical education to enable him to cope with the public and those at present in control of our municipalities.

DISCUSSION.

Mr. Robert R. Crowell.—Gentlemen: This is a very interesting paper and Mr. Leavitt assures me he will be pleased to answer any questions on this matter that you may wish to ask.

Mr. Alfred D. Flinn.—Mr. Leavitt showed us some very interesting substitutes for the street corners we have here in New York so frequently. I would like to inquire how the foreign cities manage to get the use of such valuable property, and whether or not they have to pay large damages. New York City, I am sure, would have to do so if it took such corner property and used it for fountain or other ornamental features.

Mr. Charles W. Leavitt, Jr.—I made some little inquiry about that abroad, but I did not get very much satisfaction, because most of these ornamental corners have been established a long time. Some of them are in the corners of old homes in the city. For instance, in the Palaces in Austria, Vienna, and in Rome, which I have just shown to you, and frequently in Paris, some private property was used. In many cases they are palaces or homes of very rich, patriotic people, who have given up those corners as presents to the city, and some of them established these fountains themselves. In some cases I think it came about during the wars when buildings were destroyed, and perhaps the owners, and the city, in order to fix up the street, appropriated money and simply did it arbitrarily. Of course, things are possible in Europe that are not possible here, on account of the difference in the Government, but I think in some cases they pay the damages. On the boulevards Napoleon started in Paris they have frequently damaged a great many buildings, and where a building has been cut in two it has then become part of the city's duties to replace the part destroyed, and the city retained part of it for such ornamental purposes. Our fountains on corners flow with something more valuable than water. I believe that in many cases where very handsome buildings are put on corners, if this subject is brought up when the designs are submitted for approval by the City authorities, the owners might be induced to put some such ornamental treatment on the corners, because in every tall building, the corner, if the feature was restricted to a small area, might be so arranged as to be a very great adornment to the building, and a good advertisement, and only at the sacrifice of a small percentage of the building. I do not think it is at all impossible to arrange in this way for many such improvements.

Mr. Max L. Blum.—I would like to ask the speaker whether he knows of any American city where any effort has been made to harmonize the architecture along certain streets and to determine

by law the height of buildings in relation to the street; that is, where such law has been put into effect? Also, whether any city has a check on the use of advertising signs, etc.

MR. LEAVITT.—I do not know of any city where it is being done. There are several cities where the architecture has been regulated more or less about certain centers. In Cleveland they are doing it, and out in several of the Western cities, and in Washington, but I do not think the height of buildings has ever been restricted in any American city. There are laws, I believe, which have not been observed. Laws have been passed restricting buildings to a certain height in relation to the width of the street on which they are to be constructed, but I do not think such laws have ever been enforced. I do not believe that I am familiar enough with the general city ordinances to properly answer the question, but to my knowledge there has been no such regulations, at least none that have been observed. In Paris the buildings for a long time were restricted to six stories in height, and I think they are still in most parts of the city, and it is not altogether successful. The sky line of Paris is very uninteresting. It is perfectly flat, and I am rather inclined to believe it is best to let the buildings go up, if they go up with some sort of light restriction; that is, get smaller as they go up.

The advertising in European cities is restricted very largely to these bulletin boards of which I spoke, and they are very frequent. These sign posts, as I understand it, are owned by the city, and the theatres and other people that wish to advertise pay a yearly rental for the space on them, just as the advertisers pay rent in the cars here and for space on the fences. Advertising is very frequent in the railway stations, much more than it is here; it is more disagreeable, I should say, though the advertisements are a great deal more artistic.

I do not think there is any restriction as to advertisements, except in the parks.

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THE SANITARY PROTECTION OF WATER SUPPLIES.

BY NICHOLAS S. HILL, JR.,* M. M. E. N. Y.

WITH DISCUSSION BY
ROBERT R. CROWELL, ROBERT RIDGWAY, ALFRED D. FLINN, NELSON P. LEWIS, KENNETH ALLEN, NORRIS P. STOCKWELL AND NICHOLAS S. HILL, JR.

Before entering upon the subject of this paper it is well to say that it is customary and proper to obtain a water supply from the best sources available, and to secure a normal water if possible. This is not always feasible, particularly where large supplies are involved, and hence it has become expedient to prevent or remove the pollutions which necessarily accompany human occupation of the watersheds of surface supplies.

Ground waters are not infrequently contaminated as a result of human or animal wastes, and although such supplies usually undergo natural process of purification which render them pure and wholesome, they frequently possess physical characteristics which preclude their use. The development of ground water supplies is frequently expensive in first cost, and the cost of pumping augments the expense of operation. Therefore, surface water supplies of appreciable magnitude are much more common than ground water supplies, and it is with the latter that this paper more particularly deals, for ordinarily the difficulty of obtaining pure water bears a close relation to the size of the community supplied.

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The most convenient classification of water supplies, from a physical standpoint, is:—

1st, Ground Water Supplies

2d, Direct Surface Supplies,

3d, Stored Surface Supplies.

Ground water supplies include those obtained from wells or other underground sources. Direct surface supplies are those obtained from rivers or streams, the minimum flow of which exceeds the maximum daily consumption of the communities supplied, and require no storage reservoirs for the purpose of supplementing the stream flow in times of dry weather. Stored surface supplies include supplies deriving their water from surface sources and from streams or rivers, the yield of which is not at all times sufficient to supply the maximum daily consumption, and require the construction of storage reservoirs to supplement the natural stream flow in dry seasons.

In classifying waters from a sanitary standpoint, the most obvious and useful distinction is between waters which are polluted either directly or indirectly with sewage, or in general with the waste products of human life and industry, and those which are free from such contaminations. The latter class may be called "normal." Normal waters may differ widely in character, from the pure, colorless ground water and the mountain stream to the brown water of swamps, but they have this in common, that they have never received any contamination connected with the life of man, or, in the case of ground waters, they have been effectively purified by natural processes.

One must not infer from this distinction that all normal waters are necessarily good as potable waters, but they are not capable of producing those specific infectious diseases sometimes classed as "water-borne diseases." Natural waters, such as those of springs and wells, brooks and other streams from uninhabited districts, ordinarily contain no infectious materials, and such waters, although they may contain mud, or various vegetable and even animal matters, are commonly described as "pure." It is very different with natural or normal waters which have been exposed to pollution, especially by sewage. Sewage-polluted waters may, and commonly do, contain infectious materials, as well as gross pollutions or filth.

If sewage in any form, or the waste products of human life, find their way into drinking water it is more than likely to prove a convenient vehicle for the conveyance of infectious materials into the human body.

Some forms of diarrhœal diseases, typhoid fever and Asiatic cholera are frequently the result of specific infection transmitted by water. These may be said to be the most commonly recognized water-borne diseases, for while diseases of the skin, throat, the lungs and the nose are accompanied by eruptions, exudations, expectorations or other discharges, which may find their way into sewage, these are usually insignificant in amount in comparison with the evacuations of the bowels and discharges of urine. It is not surprising, therefore, to learn that diseases affecting the alimentary canal, and especially the intestines, particularly if accompanied by diarrhœa, are most conspicuous among the diseases conveyed by polluted drinking water.

It may be well at this point to distinguish between pollution and infection. The word pollution is generally used to include infection and too much refinement in the definition of their respective signification may lead to captious differentiation; appositively the two words may imply very different potential conditions which should be understood for a better appreciation of their true meaning.

A polluted water may be said to be one which has received, and still holds, the excreta from human beings or animals, household wastes and the waste products of human industry. In general it may be said to contain that which befouls or tends to produce filth. It may contain bacteria. It may be, and usually is, infected.

An infected water is one which actually contains pathogenic or disease-producing bacteria. Such disease germs, so far as at present generally recognized, are nearly always of excrementitious origin. The typhoid bacillus, as an example, is sometimes present in an infected water.

The distinction which I wish to make manifest is that an infected water is one which may produce specific infectious diseases, which have been recognized as water-borne, although they may be produced by other media. A water may be polluted and yet not be infected or contain disease germs, but an infected water is necessarily polluted. These distinctions and definitions are arbitrary

and may not accord with the views of all sanitarians, but they are used here in a relative sense to emphasize an actual difference which exists, and they lend themselves readily to a more thorough appreciation of the respective importance of the results to be accomplished in the purification of public water supplies.

Filth and pollution in a public water supply are repugnant to the human senses, as well as to the imagination, and produce a psychological effect in the minds of people, which results in an added expense of living, due to consumers resorting to other sources of supply for drinking purposes. It is a well-recognized fact that in cities which are supplied with water which is unattractive for drinking purposes quantities of spring water and distilled water are sold. The introduction of water from extraneous sources is not without indirect danger to the health of a community, and it imposes an added burden and expense upon the health authorities of a city if such waters are properly tested before distribution. The limpid, translucent, bottled waters may be infected and therefore may constitute a graver menace to public health than an unattractive, polluted, though slightly infected public supply. The direct expense due to the enforced use of bottled waters, resulting from an unattractive public supply, is readily appreciated. The average person drinks about 1.5 quarts of liquid per day, of which one-half may be assumed to be water. Bottled water in New York costs approximately three to six cents per gallon. Therefore, at the lower figure, the cost of an auxiliary supply may be taken at $2.05 per capita per year. It is conservative to assume that 20% of the water consumed for drinking purposes in Manhattan is bottled, distilled or filtered water. The population of the Borough of Manhattan may be roughly taken at two millions. We have then an estimated annual charge of $820 000 for an auxiliary water supply for Manhattan.

An infected water, as has been indicated, may produce specific diseases such as typhoid fever, dysentery and various other diarrhœal complaints, and of late there is a growing belief that tuberculosis may be transmitted through this medium. The infectious agent in other water-borne diseases may be isolated through the development of bacteriology and a more intimate knowledge of sanitary science. Infection may then be regarded as the dangerous

element in a water supply and the one to be most seriously considered from a sanitary viewpoint, but pollution minus infection is deleterious and unwholesome. The substitution of pure water for a polluted water is often accompanied by a drop in the death rate from other diseases than the specific infectious diseases before mentioned. The effect upon the death rate from tuberculosis, infant mortality, bronchitis and pneumonia as a result of the substitution of a pure for a polluted water supply has been noted.

Mr. Allen Hazen, in his paper on "Purification of Water in America," read at the International Engineering Congress in St. Louis, called attention to the fact that after the change from an impure to a pure water supply the general death rate, of certain communities investigated, fell by an amount considerably greater than that resulting from typhoid fever alone, indicating either that certain other infectious diseases were reduced more than typhoid fever, or that the health tone of the community had been improved. In five cities where the water supply had been effectively improved, he found:

	Per 100 000
Reduction in total death rate in five cities with the introduction of a pure water supply..	440
Normal reduction due to general improved sanitary conditions, computed from average of cities similarly situated, but with no radical change in water supply.............	137
Difference, being decrease in death rate attributable to change in water supply........	303
Of this, reduction in deaths from typhoid fever was	71
Leaving deaths from other causes attributable to change in water supply.............	232

Professor Sedgwick, of the Massachusetts Institute of Technology, assisted by Mr. McNutt, has been conducting further investigations of this matter, but as yet, unfortunately, their conclusions have not been published.

The apparent improvement in the general health following the introduction of pure water may be due to the elimination of specific bacteria and infections, or to the prevention of pathological effects

produced by impurities in the water. I think I am warranted in saying that pollution *per se,* in the restricted sense in which it is used in this paper, may tend to lower the vital resistance of the human system and hence render it more liable to disease. Bronchitis usually results from lowered vital resistance and not by the spread of germs, although there may be germs concerned. The apparent diminution in the death rate from this disease, following the substitution of a pure for a polluted water supply can only, at present, therefore, be accounted for by the second of the two hypotheses, suggested as the cause for the improvement of the health tone of a community following such substitution. So far as present knowledge goes, pollution is not only objectionable from an economic and psychological standpoint, but it is also unwholesome.

There are certain physical characteristics which may also affect the attractiveness of a water and which relate more particularly to the æsthetic features of a water supply, although the hardness has a direct economic bearing on its value, both for domestic and industrial uses. The physical properties of a water are usually classed as color, odor, turbidity, taste and hardness. Pollutions increase the first three and certain trade wastes may also increase the hardness. The removal of pollution reduces the color, odor and turbidity, and in some cases the taste, although it may not reduce the hardness and hence such removal increases the attractiveness of a water supply. Microscopic organisms flourish in some waters and they may produce odors and disagreeable taste, but they are not necessarily injurious to health.

Having thus tersely discussed the various characteristics of a water supply which tend to depreciate it in the mind of the consumer, or else render it unwholesome or even dangerous to the health, it is evident that while its physical properties should receive proper consideration, both from an economic and æsthetic viewpoint, pollution and infection are by far more important in their bearing on public health, and their removal has the greater economic value. I may add this point that it is fortunate that the same processes which remove pollution and infection usually improve the physical characteristics of a water, and a pure and wholesome water is usually attractive.

What are the present standards for a pure water supply and

how are they determined? The quality of a water, prior to the advent of bacteriology, as applied to the examination of water, was judged from a physical and chemical analysis. The physical examination of a water is no index to the pollution and infection it receives. The chemical analyses alone may sometimes fail to distinguish a normal from a sewage polluted surface water. Standards of purity of water based on the amount of nitrogen compounds it contains (the nitrogen compounds and chlorine being the chemical indices of pollution), are of doubtful value. The best standards of to-day require that water for drinking purposes should be subjected not only to a physical examination and chemical analysis, but to bacterial and microscopical examinations as well. In other words, a public water supply must be clean and soft, free from odor and taste, as determined by the physical examination; free from pollution, as shown by the chemical and bacterial examinations; free from infection, as indicated by the bacterial examination; and sterile in micro-organisms, which may produce unpleasant odors and tastes, during the processes of storage and distribution. In addition to all these tests a careful inspection of the source of supply is essential, and obvious pollutions should be removed even though the water supply complies with all the best standards for the laboratory tests above described.

The surface waters on the Atlantic Coast are usually soft, and it is unnecessary to resort to artificial water softening, but as the density of the population increases it becomes more and more difficult to obtain a normal surface water in large quantities, except at prohibitive cost, and it has not been found practicable to develop extensive ground water supplies except in certain restricted localities. It has become necessary in dealing with large cities, and frequently with smaller cities, to convert an impure into a pure water supply, and this exigency has given rise to the development of modern sewage disposal plants and filtration.

Sewage purification deals with the elimination of nuisances coming from household and trades waste. Sewage disposal involves prevention of pollutions and their removal at the source of manufacture. There are two nuisances which are conspicuously due to sewage. The first is caused by conditions that are offensive to the senses of sight and smell; the second class of nuisances is associated

with the disease germ contained in sewage and which may be transmitted to neighboring communities through the water of the stream into which the sewage is discharged. The sewage to be cared for in any given watershed varies widely in its composition and amount, depending upon the extent of urban population in the watershed, the volume of water used per capita by the inhabitants of the urban communities, the quantity and character of the trades waste, and finally on whether there are sewers and, if so, whether they receive storm water and street wash in addition to the household and trades waste.

At the present time, for the purpose of the protection of public water supplies, the separate system of sewers, which deals with household and manufacturing wastes exclusively, is considered sufficient to remove chronic danger from infection and gross and noxious pollutions. Sewage from communities tributary to surface water supplies should be very thoroughly purified by filtration through sand, or by sterilization following preliminary treatment by sedimentation and sprinkling filters or contact beds. No hard-and-fast rule can be laid down in this matter, the degree of purification depending to some extent upon local conditions on the watershed, the amount of dilution and the time required for the sewage effluent to reach the intake of a water supply.

Enough has been said above, it is believed, to make it plain that there are different types of problems which can be solved by different types of treatment in order to meet thoroughly all reasonable sanitary requirements, but if sewage which is to be treated in purification works is to be filtered or properly stored before the water supply is delivered to a community, the degree of purification required may be somewhat modified, but it is essential that such sewage purification should in all cases remove a high percentage of bacteria and gross pollution.

So far as can be judged from a study of the literature on the subject and official documents, the question of sewage purification was first raised in 1842 by the English authorities in a report by Sir E. Chadwick on the health of the working classes. Mention there is made of the Craigentinney Meadows, near Edinburgh, which are said to have been first used in the eighteenth century. These, however, were by no means irrigation areas in the larger

sense of the term. The sewage of a part of Edinburgh flowed in open rubble drains on the meadow lands and it was soon observed that where the sewage reached the grass grew abundantly. Hence ditches were dug in all directions in order to get the sewage on to sterile patches that these might also bear a crop. The value of the observations on the Craigentinney Meadows lay, however, in the fact that they showed that sewage could be dealt with on land for many decades without the latter losing its efficiency as a purifying agent. "Broad irrigation," as this method of treatment was called, has been abandoned on account of its cost, and numerous more modern processes have been substituted therefor. As at present employed, proper sewage purification involves, first, sedimentation. Sedimentation is effected by allowing the sewage to flow into large tanks or receptacles, capable of storing the sewage in a quiescent state for several hours. This results in the deposition of the heavier suspended matters and allows of the more efficacious treatment of the effluent from the sedimentation tanks, by other processes. Sometimes the sewage is passed from the sedimentation tanks directly to sand beds, usually of a depth of about three feet. The sewage is applied to these beds intermittently, by means of dosing chambers, automatically controlled. The effluent from the sedimentation tanks may be applied to contact or sprinkling filters, consisting of broken stone to a depth of several feet. The contact beds are operated on the fill-and-draw plan, the sewage being applied intermittently and allowed to remain in contact with the broken stone for proper periods of time, after which it is drawn off and passes on, either to secondary contact beds or to sand filters. With sprinkling filters the sewage may be applied through nozzles or sprays, or perforated pipes, either continuously or intermittently, the spray from the nozzles or pipes falling on the top of the beds and trickling through the stone to the concrete bottoms or basins on which such beds are usually built, from whence it passes off for subsequent treatment as before.

The action upon sewage, in a contact filter, while essentially effected by bacterial agencies, is also to a certain degree the result of certain physical phenomena peculiar to the process. The two actions combine to effect a material clarification of the sewage affecting both the suspended and dissolved matters and resulting

in a more or less complete oxidization of the unstable complex organic compounds contained therein. When a contact filter is emptied, air is drawn in, resulting in a partial oxdization of the organic matters which adhere to the particles of the filtering material when the sewage is discharged from the filter. While the pores of the filter are filled with air, aerobic bacterial activity flourishes. Upon filling the filter with sewage oxygen is rapidly exhausted and as a result the process of oxidization ceases. There follows a period of anaerobic action which effects a substantial modification of the organic matters, resolving them to simpler forms, to be acted upon by the oxidizing agency which again becomes active upon draining the filter. The resulting effluent of a well-constructed contact filter, operated at a reasonable rate, is usually free from high amounts of suspended matters and the putrescible matters contained in the sewage are changed into non-putrescible forms. When a single contact does not succeed in effecting this result the effluent of the first filter is discharged on to a second, and by means of the double contact a stable effluent is obtained. The per cent. of bacterial removal, however, from such beds is not sufficiently high to warrant the introduction of their effluent into potable water supplies without sterilization or subsequent treatment on sand.

In the present day sprinkling filters the sewage is continuously applied to the filters for long intervals at a time in the form of a spray, the filtering material being coarse and thoroughly underdrained. This aeration of the sewage applied to the filters causes the liquid to be, in round numbers, saturated about 80% when it reaches the filter surface. This aeration and the use of coarse material permits a non-putrescible effluent to be obtained at far higher rates of operation than is the case with the contact beds. In a sprinkling filter which is properly constructed and properly operated the action which takes place upon the passage of the sewage through it is essentially aerobic, instead of being a combined aerobic and anaerobic action, as is the case in contact filters.

From a physical standpoint there is much in common with the action in sprinkling filters and contact filters. Each acts to a material degree as a strainer. As the sewage percolates through the filter much of the suspended matter is deposited upon the surface

of the beds or filtering material and thin gelatinous films are formed about the grains of the material. As in contact filters, it is these films which play a most important part in the purification effected by the filter, due to their power of removing by absorption a certain proportion of the dissolved organic matters contained in the sewage, and of acting as oxygen carriers. The bacterial efficiency of the sprinkling filters is not sufficiently high to warrant their effluents, after treatment, to be emptied directly into potable water without sterlization or a subsequent finishing treatment on sand, unless the point at which the effluent is delivered to the stream is at a great distance from the point of intake or the dilution of the effluent is exceedingly high.

The principle of the operation of sand filters, whether as the only method of treating sewage effluents after preliminary sedimentation, or when used as a finishing process in connection with contact beds or sprinkling filters, is practically the same as the operation of sand filters applied to the purification of water.

Filtration of a water supply may be differentiated from sewage purification in so far as it removes pollution but does not prevent it. Filtration, in the sense in which the word is used in this paper, has for its object the removal from water of objectionable polluting matter that cannot be economically taken out by preventive measures, by simple subsidence, or by chemical treatment. In conjunction with sewage disposal works, or as supplemental thereto, filtration is designed to remove acute danger from infection or spasmodic pollution, as well as to remove the danger due to isolated infections from rural districts. Filtration also improves the physical properties of a water and in a great measure removes filth and pollution by removing organic matter of excrementitious or vegetable origin. The successful filtration processes for purifying the water-supplies of cities and towns may be separated into two classes. The distinctive characteristics of these classes are as follows: In one, first adopted in England, the water is filtered slowly through beds of sand; filters of this type are called English Filters, Slow Filters or Slow Sand-Filters. The second type, a distinctively American invention, filters the water rapidly through beds of sand, a coagulant having first been added to the water; filters of this kind are called American Filters, Mechanical Filters or Rapid Sand-filters.

Both methods are in use. For the sake of uniformity, in the present paper the terms Rapid and Slow Sand-filters will be used in referring to the two types.

The process of slow sand-filtration consists of passing the water downward by gravity through beds of sand of certain depth, and with certain restrictions as to velocity and manipulation that experience has shown to be necessary. By this process most of the suspended matters in the water, including nearly all of the bacteria, are retained upon the surface of the sand; most of the remaining bacteria are destroyed in the top layers of the filter, while a portion of the dissolved organic matter in the water is converted, by chemical action, into inorganic compounds. Recent investigations have shown that in slow sand-filters in efficient service, giving a normal reduction of bacteria, a film of gelatinous material forms around the sand grains whereby most of the bacteria are mechanically retained under conditions that are unfavorable to their development. This gelatinous material is composed probably in part of colloidal matters and in part of dead or resting bacteria.

The process of rapid sand-filtration consists of passing the water downward at a rapid rate through small beds of sand, a certain amount of coagulating material having been first introduced into the water to assist in forming a scum on the surface of the sand and a film between the grains of sand in the bed. The bacteria and suspended matters in the water are largely retained in the filter-bed. The coagulant may also reduce the color and dissolved organic matter in the water to a much greater extent than would be possible with slow sand-filters.

In the rapid sand-filters an artificial gelatinous film is formed by the introduction of the coagulant. The material usually employed is sulphate of alumina. The action of the sulphate of alumina, however, is not limited to the removal of turbidity and bacteria; it possesses the property of combining with the coloring material dissolved in the water, breaking it up and precipitating it with the suspended matter. This property is very useful in the treatment of dark-colored waters derived from swamp lands and rivers having long contact with leaves, grass, roots and decaying organic matter. The alum has also the power of uniting to a certain extent with the organic matter in solution in the water, and thus

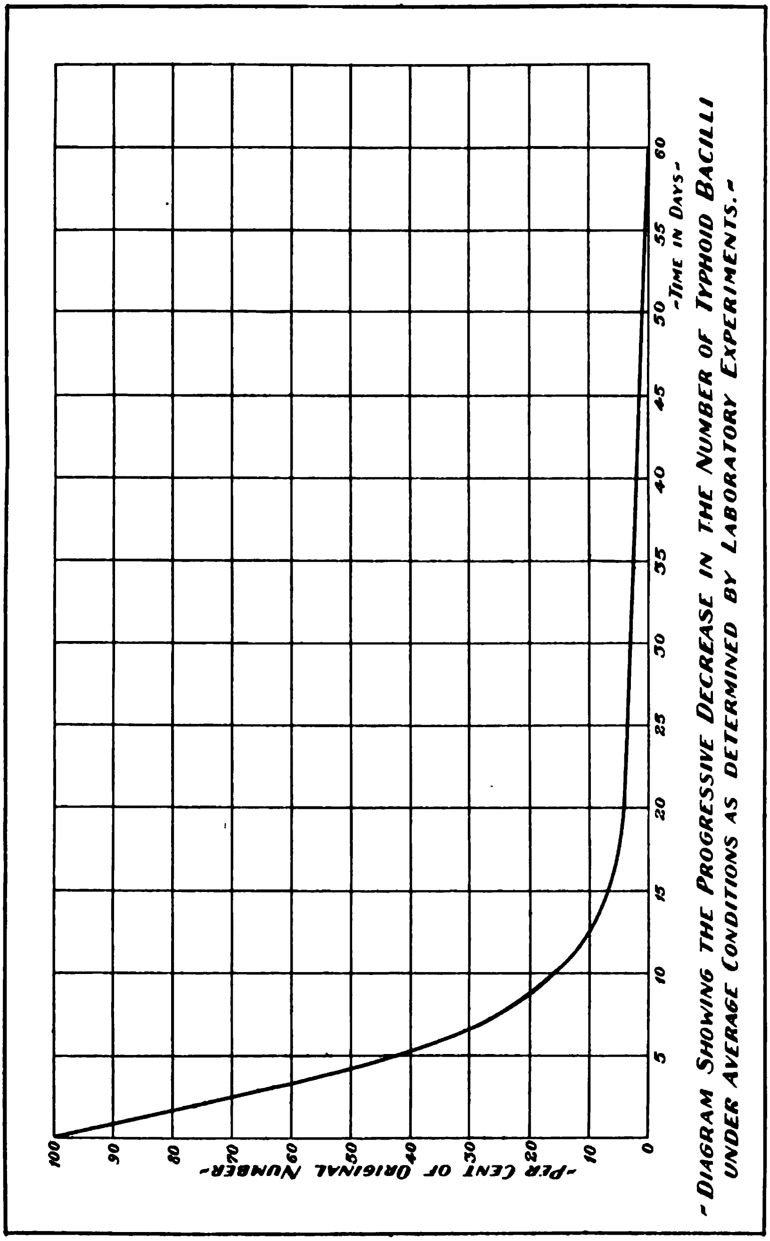
brings about a higher chemical purification than the ordinary slow filter, without alum, can accomplish.

Which of these methods of purification is preferable, in any given case, must be determined from careful consideration of the quality and character of the water, the results desired and the relative costs of the processes, both for the installation and operation.

The bacterial efficiency, or the percentage which the number of bacteria found in the filter effluent is of the number of bacteria in the raw water, is more dependent upon the operation of the filter than upon the type of filtration process employed. Experiments, with special growths of bacteria at the Lawrence Experiment Station, indicate that the hygienic efficiency is probably fully as great as the bacterial purification. Hygienic efficiency is usually regarded as the percentage removal by filtration of the bacteria capable of producing diseases. The percentage basis in expressing bacterial efficiency is unfair because with water low in bacteria the percentage will be very high. With polluted water it may still be high and yet allow a great number of bacteria to appear in the effluent, and therefore it is usually customary to base a standard of purification upon the maximum number of bacteria per c.c. allowable in the effluent from a filtration plant. The German standard of 100 bacteria per c.c. as a maximum number of bacteria allowable in a filter effluent has been very generally accepted.

It is pertinent to refer briefly to the protection afforded water supplies by the natural processes of purification due to storage and sedimentation. The curve shown on Plate 17 illustrates the progressive decrease in the number of typhoid bacilli in water under different conditions, as determined by laboratory experiments. The germ of typhoid fever does not multiply in water under laboratory conditions and presumably it does not multiply in water under natural conditions. It may live in water for several months but in ever decreasing numbers. The Croton watershed has, therefore, in its large storage reservoirs, one great safeguard against danger from infection. The curve indicates the rapid initial decline in the number of bacilli following inoculation, followed by the continued existence of the more hardy individuals, and finally the extinction of all. The curve tells in a general way the effect an unfavorable environment has upon these bacilli. In addition to the environ-

PLATE 17.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
HILL ON THE SANITARY PROTECTION
OF WATER SUPPLIES.



-Diagram Showing the Progressive Decrease in the Number of Typhoid Bacilli under Average Conditions as Determined by Laboratory Experiments.-

mental influences, sedimentation and other factors are at work in storage reservoirs, which materially reduce the danger from an infected water. Dr. A. C. Houston, of the Metropolitan Water Board in London, has just published his third research report on the reduction of water bacteria by storage, and emphasizes the differences that must be considered in providing reservoir capacity for storage purposes only, and in providing storage for bacterial reduction. Time will not permit of anything but a mere reference to this important factor in the design of storage reservoirs for water supply purposes. The physical and chemical improvement of water through storage is sometimes notable.

It is important that the inlets and outlets of reservoirs designed for purposes of purification should be arranged so as to permit of as complete a circulation of water as possible. If this matter is not attended to part of the water leaving the reservoir may have been driven by surface currents from inlet to outlet with practically no storage, while other parts may have been stored for a length of time not necessary for the purposes of safety. Over-stored water may dilute and mask the bad qualities of the under-stored water, without destroying its potentially dangerous qualities. A storage reservoir in which the circulation of water is imperfect is economically a failure so far as the purification of water is concerned. Conditions of stagnation may result in encouraging growths of algae. Dr. Houston in his report also refers to the difficult question of whether the storage of raw water should be fixed on a maximum or on a minimum basis. He says, speaking of the Metropolitan Water Board, "If the Board elect to store raw water on a minimum basis, it would be necessary to build reservoirs capable of holding far more than the maximum supply of water. On the other hand, if the Board decides to store water on a maximum basis this means that occasionally it will fall short of the necessary amount to provide for proper sedimentation." It may be seen from this that other considerations than mere storage must necessarily be reckoned with when dealing with reservoirs as a part of a purification system for a public water supply.

Reverting to filtration and sewage disposal, the author has been surprised at discussions which have occurred from time to time regarding the relative efficiency of the two processes as methods of

protecting public water supplies from pollution and infection. They are not alternative processes, but supplemental and co-ordinate. The best sanitary standards of safety and decency demand the removal of all preventable pollutions at their source. This is the function of sewage disposal plants, so far as this pollution is derived from towns in the watershed, particularly where such towns have water supplies.

When dealing with stored surface supplies a proper sanitary patrol, to prevent isolated nuisances, should be maintained, and in many instances the purchase of strips of land, two hundred to three hundred feet wide, along water courses tributary to the supply and around all reservoirs, is necessary or expedient, to remove the danger from small communities and the farming sections, or from the itinerant population. In villages without water supply the pail system for the removal of human discharges should be resorted to. In no case should a nuisance of any kind be permitted immediately over or adjacent to a flowing stream forming a part of the water supply.

A watershed with a density of population not greater than one hundred per square mile, cared for in the manner above outlined and provided with storage reservoirs, properly designed and located to obtain the full effects of sedimentation and bacterial reduction, with a minimum capacity equivalent to at least one hundred days' supply, will produce a water reasonably free from pollution and infection, although it may not be attractive. Such a water would produce a reasonably low typhoid fever death rate, probably not exceeding twelve per one hundred thousand,* provided the other santitary conditions in the community using the water are good. This is but a tentative statement and can only be accepted as such. The distance of the center of population above the point of intake, the character and slope of the watershed, and other considerations might modify a statement of this kind.

New York and Boston, however, furnish excellent examples of communities supplied with water under conditions above outlined. In these communities the typhoid fever death rate is sixteen and twenty respectively. In New York and Boston, however, the system of sewage disposal is comparatively poor and a portion of this death rate is attributable to this cause. Notwithstanding the poor sewage

disposal of these communities they stood respectively 116 and 81 from the top out of 136 cities reporting typhoid fever rates in 1902.

The diagram shown on Plate 18 was taken from the report of the Merchants' Association of New York, and illustrates typical curves showing the typhoid death rate under differing sanitary conditions.

Sometimes it is expedient, owing to financial considerations, to obtain a supply of surface water directly from large rivers in the immediate vicinity, without impounding or storage. If such streams are polluted to a greater or lesser degree, filtration should be resorted to. The remedial measures suggested for stored surface supplies would be prohibitively expensive under these conditions. The low typhoid fever death rate reported from communities having supplies of this character furnishes an excellent testimonial of the results accomplished by such plants. Bayonne, Hoboken and Albany are examples of this. Bayonne uses the raw water directly from the Passaic River filtered through a mechanical or rapid sand-filter. Hoboken derives its supply from the Hackensack River, after storage and treatment in the same manner, and Albany is supplied with water derived directly from the Hudson River, after being passed through slow sand-filters. It is fair to state that about one-third of the Albany supply is from other surface sources and is unfiltered. All three sources of supply are polluted. The death rates from typhoid in 1907 were: Bayonne, 19; Hoboken, 17; and Albany, 23.

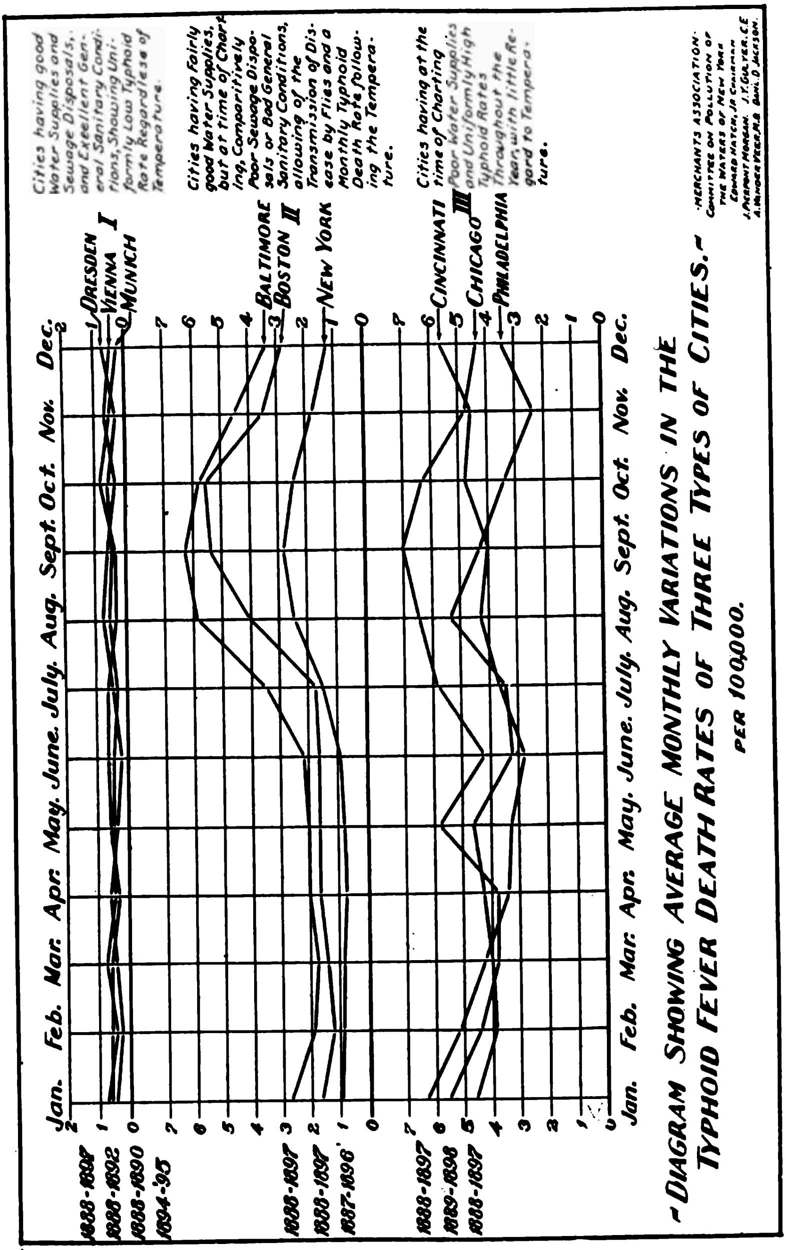
Comparing the methods of preventing pollution practiced in New York and Boston with filtration as used in the other places mentioned, so far as indicated by the typhoid fever death rate, there seems to be no decided difference in efficiency. As to relative costs, no comparisons can be made owing to the many varying factors affecting the cost. The quality of water to be filtered, the population to be sewered and the amount of sewage to be treated, are among these factors. Recently I had occasion to prepare plans for, and make estimates of, the cost of protecting a public water supply of 50 million gal. per day. Water was obtained from surface sources and impounded. The watershed contained 121.5 square miles, the density of the population was two hundred and five per square mile and the urban population was 16 000. The center of urban population was 9.7 miles, or 18 hours, above the point of intake. Such

conditions require efficient purification of sewage. The cost of providing sewers and disposal works for 70% of the urban population was $823 671.55, and, adding the capitalized cost of operation, the total cost was $1 121 133.77. Compared with this a mechanical or rapid sand-filter of 50 million gal. daily capacity cost $485 138.02, and, adding capitalized cost of operation, the total cost was $1 285 138. Generally it will be found that where conditions require impounded surface supplies and storage to provide the necessary yield, where the consumption exceeds 1 000 million gal. per day, where the density of the population on the watershed does not exceed one hundred per square mile, the prevention of pollution as outlined will be slightly cheaper than filtration. This statement, as well as others of like nature, is necessarily tentative and subject to many modifications, but it serves to direct the mind to just conclusions.

As previously intimated, neither of the above conditions fulfill all the requirements for a pure water. Where water is but slightly polluted and the amount of pollution is not subject to wide variations, efficient filtration may alone suffice. On the other hand, the sufficiency of filtration of polluted waters, subject to variation in the amount of pollutions due to rainfall and freshets, without proper storage or the previous removal of gross pollution, is to be seriously questioned. In the case of a community like Albany, deriving its supply from a large river, it would be manifestly impossible to undertake the removal of the pollutions from the large communities of like size above. Under conditions like this, State legislation regarding the pollution of potable waters is the only safeguard. The State should require communities contributing gross pollutions to potable streams to provide for their efficient removal, but where cities of large size derive water from rivers or streams of insufficient size to furnish an adequate supply without storage, where such cities preempt the territory formerly occupied by smaller communities for reservoir construction or sanitary protection and find it necessary to remove pollution from towns already existent, the expense should be borne, at least in part, by the city benefiting by such constructions and the blessing of a pure water supply.

It is doubtful if the removal of sewage and efficient storage is a sufficient safeguard or produces a water supply which accords with

PLATE 18.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
HILL ON THE SANITARY PROTECTION
OF WATER SUPPLIES.



modern sanitary requirements. Such precautions will not necessarily produce an attractive water. The variation in the amount of pollutions due to rainfall and freshet, will not be properly provided for and water of doubtful quality and giving occasionally bacterial counts above normal will result. Filtration is necessary as a finishing process to prevent spasmodic pollution and infection, as well as the effects of isolated infection. It appears, therefore, that two things are essential in all impure surface water supplies:

First, the prevention of pollution.

Second, filtration.

Whether this result is obtained by legislation, providing for efficient sewage disposal at the expense of the offending community, or is procured at the expense of the city obtaining a pure water supply, is immaterial to the sanitary principle involved. Economical considerations will undoubtedly modify the above conclusions in special cases, but the principle is unassailable, and the results of its practical application are usually economical, although it is difficult to produce figures which will convince the taxpayer that such is the case. It is, however, gratifying to see that the idea of preventing pollution is yearly taking deeper root in the public mind as expressed in recent legislation in Ohio, Pennsylvania, Indiana, and other States.

The cost involved is incommensurate with the benefit derived. The cost of filtration varies from \$6 to \$11 per million gal., including operating cost and fixed charges. This amounts to 1.1 cents per 1 000 gal. at the higher figure given. If we assume 70 gal. of water per day for domestic uses, this would amount to a charge of \$0.281 per capita per year.

The cost of sewage disposal and other sanitary measures depends upon many factors and cannot be estimated except in specific instances. It is safe to assume that such measures, in large communities where the expense should be borne by that community, will not exceed the cost of filtration, therefore the total cost per consumer for a domestic supply may be estimated roughly at \$0.562 per year. It would not require a large reduction in doctors' bills to offset this. Deduct the cost of bottled waters. Add the improvement in health tone and capacity for work. Deduct lost wages due to water-borne sickness. Deduct the loss from death, which cannot

be computed in dollars and cents. It does not require extensive computations to reduce the whole proposition to an economical test and prove its financial value.

It is an interesting question to-day, as previously outlined, whether mere pollution apart from infection with specific disease germs, is in itself detrimental to the public health and hence we must have clean water as well as uninfected water. No water, the pollution of which has not been prevented, and from which filth has not been removed, will meet the standards of modern sanitation, however much specious economic considerations may defer the achievement of such a standard.

This paper would scarcely be complete without some reference to modern developments in the chemical treatment of public water supplies by the use of hypochlorites derived by the application of chloride of lime to water, or else by the electrolytic treatment, wherein solutions of common salt are put into an electrolytic cell and an electric current allowed to pass through this solution of salt, the salt being broken up into its sodium and chlorine portions, forming sodium oxychloride, which is very similar to the calcium hypochlorite in its action and which forms the active portion of the bleaching powder of chloride of lime when added to water.

The application of either chloride of lime, in which the active agent is the hypochlorite of lime, or hypochlorite of sodium, produces the same result. The free carbonic acid found in most waters releases the hypochlorous acid from either hypochlorite of lime or sodium and it is the hypochlorous acid, a very strong oxidizing agent, which acts upon bacteria and to some extent, depending upon the amount applied, on the organic matter in the water. The theories of the exact chemical changes occurring with the application of hypochlorites to water vary somewhat and its use has involved some discussion as to whether oxygen liberated from hypochlorous acid or chlorine is the active disinfecting agent. These questions, however, are not pertinent to the underlying principles governing the use of such chemicals but are incidental as affecting the conclusions which follow regarding the application of hypochlorites to the disinfection of water.

As the sole means of purification of a public water supply this method is to be deprecated. The cheapness with which the process

can be applied adds very much to its attractiveness. These chemicals act purely as disinfectants. Their bacteriacidal efficiency is not to be questioned and hence their continuous application in proper amounts removes danger from infection, but it is doubtful if these chemicals can be applied to water in quantities sufficiently large to oxidize the organic matter in a surface water to an appreciable degree, and hence remove the putrescrible filth which is found in all polluted waters. So far as present indications go these chemicals seem to have a selective action and they apparently eliminate bacteria without seriously affecting the organic compounds present in the water. If it is attempted to oxidize organic matter by the use of hypochlorites the amount of hypochlorous acid or free chlorine, present in the water as delivered, may be sufficiently high to cause an inhibitive action on the processes of digestion in the human stomach. Nothing definite is known in regard to these matters and hence the process is in an experimental state and should not be tried as the sole method for purifying a public water supply until much more is known about its action.

If the chemical is applied in quantities sufficiently small to remove the danger of the inhibitive action on human digestion, then, in a water supply which has received sewage pollution, the putrescible organic matter, either animal or vegetable, is acted on to a very slight degree, and hence all of the pollutions outside of the infectious agents present therein are allowed to pass on to the consumer. The chemical purification under these conditions is nil. This is not desirable in the light of the present development of sanitary science. The process is not a complete one and only performs the specific function of removing bacteria. It does not improve the physical character of a water, or render it more attractive. It may not be applicable to all waters and under some conditions may not be efficient as a bacteriacide. The amount necessary to be used depends upon the amount and character of organic matter present in the water treated, and hence its use involves intelligent technical supervision. The manner of application is also important. Water thus treated should be stored and subjected to sunlight and aeration before distribution, as these agencies remove any excess of chlorine which may be present, or else it should be filtered, as the decomposable organic matter on the filter surface combines

with excess hypochlorous acid, released in the water, and hence removes any danger from this source.

As an accessory to filtration, the use of such chemicals offers a very promising field, and its adaptation to such proper uses will no doubt materially reduce the cost of filtration. The application of hypochlorites to sewage effluents removes the danger of infection and this use of bleaching powder and common salt has been the subject of the most careful experimentation at the research laboratory of the Massachusetts Institute of Technology for a period covering three years.

It has been found that, if applied in proper quantities, the germicidal efficiency is very high, and hence, as a finishing process to sewage disposal, removes the greatest danger to be feared from the introduction of sewage effluents into potable water. The application of these chemicals advisedly and with proper consideration of their real function will no doubt mark an epoch in the purification of public water supplies, but they should only be used in connection with chemical precipitation and sedimentation or filtration, which remove the filth and pollution, as well as the infectious agents present in a public water supply.

DISCUSSION.

MR. ROBERT R. CROWELL.—We have listened to this very interesting paper this evening on a subject which, at present, is taking up a great amount of time and thought of the public officials, and I hope it will bring out a fair discussion. If any one desires to ask the author any questions, he will be pleased to answer them. Mr. Ridgway, have you anything to say on this matter?

MR. ROBERT RIDGWAY.—New York is now reaching out to the Catskills for water. The new source of supply is so far away and the impounding reservoir so large, that some of the dangers that have been mentioned to-night will be eliminated. The Ashokan Reservoir will impound over 120 billion gallons of water. At 500 million gallons daily this means over 240 days' supply. This affords an opportunity for the water to settle and bleach before it starts on its long journey of 80 odd miles to the City, in addition to which it will go through an aerating process immediately after leaving the reservoir.

A MEMBER.—I would like to ask the author to give approximately the cost, say per million gallons, of using chloride of lime to purify sewage effluent which has passed through a filter bed, from bacteria.

MR. HILL.—The cost of the chloride of lime treatment is dependent upon the amount of organic matter present in the sewage effluent, and, of course, that, in turn, is dependent upon the character of treatment which the sewage receives before the effluent is discharged into the stream. The results of the experiments at the Massachusetts Institute of Technology seemed to show that the effluent from the sprinkling filters, after being settled, required about three parts per million of chlorine to properly effect a complete bacterial removal. If you apply chloride of lime to the raw sewage, then it requires ten parts of chlorine per million, and if you take the effluent from a septic tank it requires from twelve to fifteen parts per million, the amount of organic matter in the septic effluent being no higher than in the raw sewage, but the character of the organic matter in the effluent of the septic tank being different. It is evident that the cost of such a process depends very materially on the preliminary treatment which the sewage receives. Chloride of lime, however, is very cheap and it only costs about $25 a ton, delivered in these parts, a fraction over a cent a pound. Therefore for three parts per million of available chlorine the cost would probably not exceed, I should say, $1 to $1.50 per million gallons.

MR. CROWELL.—Has Mr. Flinn something to tell us about this matter?

Mr. Alfred D. Flinn.—Mr. Ridgway has referred to the safety of the new supply from the Catskills due to the large storage reservoir and the long distance the water would have to come. In building this long aqueduct, however, the Croton watershed has to be crossed at a point much nearer the City than the Ashokan Reservoir in the Catskill Mountains. It has, therefore, seemed wise to guard the existing supply with the utmost care against any possible contamination during the period of construction, and for this purpose carefully drawn specifications have been inserted in the contracts for construction across the Croton watershed, particularly near Croton Lake. These precautions extend to a personal examination of the laborer for employment on this work on the watershed to detect and remove cases of so-called walking typhoid, or any other communicable diseases; the constant care of the workmen kept in these camps, to guard against the introduction of any communicable disease and to maintain a model state of health among them. Furthermore, the excreta are to be burned by the use of portable or other incinerators, a type having been adopted which we believe has been perfected and found efficient in other places.

The drainage water from the tunnel, which, as any engineer knows who has been in tunnels during construction, is liable to become foul, is to be filtered or otherwise treated. The waters draining from the spoil banks of these tunnels is also to be treated, and also the drainage water from the camps, including the wastes from the cesspools, the kitchens, the laundries and the bath houses. Every care is being exercised to guard not only New York City's water supply, but other public and private supplies which might possibly be affected by our construction. To some of us, when we look at the condition existing on some of these streams,—and permitted to exist every day in the year,—our precautions seem almost ludicrously careful. When we go to such particular pains to prevent all chances of contamination and see on these same streams privies and other sources of contamination very near the points where the water is taken, we trust, at least, that there will be small ground for charging the Board of Water Supply with any epidemic if such should occur during the period of our work. It will be interesting to see how successful these specifications are and with what co-operation the contractors meet the engineers and the other officials of the City in carrying out such an endeavor to safeguard the public health.

Mr. Crowell.—We have here this evening the first President of this Society, Mr. Nelson P. Lewis, and I think he will be pleased to say a few words on this subject, as he, as Chief Engineer of the Board of Estimate and Apportionment, has really had this whole matter under his jurisdiction.

Mr. Nelson P. Lewis.—Mr. President: I do not think that I can contribute anything to the discussion of Mr. Hill's very excellent and carefully written paper.

It is interesting, however, to note that after all the controversy as to which is the better treatment, removal of contamination from the watershed or purification of the supply after it has been collected, this learned doctor says "do both"; and he shows that it will cost relatively little.

I would like to take this opportunity to ask some of the representatives of the Board of Water Supply whether or not the so-called typhoid fever epidemic in Peekskill a year or two ago, which the Peekskill people were disposed to charge to the City of New York or its contractors, was due or traceable to the City or its work on the aqueduct section in the neighborhood of Peekskill.

Mr. Crowell.—Possibly Mr. Flinn will answer that question.

Mr. Flinn.—Mr. President: I think Mr. Ridgway can answer that question. Peekskill is in Mr. Ridgway's territory. To the best of my knowledge the epidemic mentioned was not chargeable to New York City's work.

Mr. Ridgway.—Some of the local people were inclined to charge the epidemic to the camp of our contractor for the section of aqueduct lying in the Peekskill watershed. It is natural for a community to attribute the blame for such an epidemic to a camp of alien workmen rather than to charge it to sources of pollution that have existed for many years. After the epidemic had started, an inspection of the watershed was made by the local authorities, who reported something like 30 violations of their sanitary regulations, one of the thirty being at the contractor's camp in question. The latter was located more than 2 miles from Peekskill Creek, from which the supply of the village was drawn. Between it and the creek was a large swamp, through which the drainage of that part of the watershed in which the camp was located had to pass before reaching the main stream. The physician employed by the contractor to look after the health of his employees and to regulate the sanitary affairs of the camp, reported that no case of illness resembling typhoid had occurred on the work or in the camp since the latter was established. Careful investigations, both on the part of the City's Board of Water Supply and the village authorities, failed to show that the camp was to blame. Among other violations reported, were such nuisances as privies, pigpens, cowyards, etc., on the farms within a short distance of the main stream and its tributaries.

Mr. Kenneth Allen.—Experiments in sterilization with chlorine were made by the Baltimore Sewage Commission in connection with their new plant. While I do not know what conclusions were finally

reached as to its adoption there, I understand the cost was between 75 cents and $1 per million gallons of effluent coming from septic tanks and sprinkling filters.

MR. CROWELL.—Is there any other member desires to discuss this matter?

MR. NORRIS P. STOCKWELL.—I would like to ask one question referring to the diagram shown (see Plate 18). In the lower lines there is a great increase in the tyhoid in warm weather. I think Mr. Hill stated that in a way you might say that the typhoid due to the water supply was constant throughout the year. Would not the warm weather and the warm water have something to do with the increase of bacteria? Could you say the typhoid due to the water supply would be constant during the year? Would it not increase in the warm weather?

MR. HILL.—I do not believe that definite conclusions can be drawn from comparative curves of the kind here presented, but it is very interesting to note that in the cities on the upper lines, in which the water supply is normal, and where the other sanitary conditions, such as sewage disposal, are properly provided for, you get a low and constant death rate from typhoid. The very sharp rise in the summer months can hardly be attributed to the water supply. You would expect, from the water supplied, if found polluted, to find complications depending on other conditions than the temperature; you would expect a rise in typhoid to follow the spring freshets, or the periods of very high rainfall. Other conditions would tend to increase the bacterial contents of the water, and hence disease-producing effects. The curves as shown here are the results of study by Dr. Jackson, who has given a great deal of time and attention to this matter. He has gone so far as to count the number of bacteria on flies and determine the season of the year at which flies are most numerous, and has used other means of getting data which would corroborate the theory that the peaks in the curves for Baltimore and Boston in the summer season are attributable to other causes than water. It would seem to me much more natural to find a rise such as you see in the lowest curves, for cities with impure water, in the spring of the year, at the time of bad spring freshests, at the time of the overturning of reservoirs. You should find conditions of this kind rather than this steady increase before, and gradual decline after, the period of hot weather, if the water alone were responsible, particularly as in conjunction with these curves Dr. Jackson has prepared tables which show that the curve corresponds almost exactly with curves showing the increase and decrease in the number of flies during the summer season.

MR. CROWELL.—Does any other gentleman wish to be heard in this matter?

A Member.—The author has forcibly referred to the pollution of water in streams. I am almost positive in the European countries there are national laws regulating the pollution of their streams. I would like to ask if there are any national or state laws in this country doing the same thing?

Mr. Hill.—I think I referred in the paper to recent laws of Ohio, Indiana and in other states. New Jersey now has laws in regard to the pollution of potable waters. The State Sewerage Commission has the power to compel communities who are polluting streams to remove the pollution. Pennsylvania is taking up the matter and is exercising a state supervision of all potable waters. New York is taking up the question, although I am not positive whether the law which is proposed by the President of the State Board of Health was passed at this last meeting of the New York Legislature or not. Massachusetts has for some time exercised an advisory authority over the matter of pollution, and the Legislature in Massachusetts has gradually increased the power of the Massachusetts State Board of Health in regard to the pollution of public water supplies.

Mr. Kenneth Allen.—The last question brings up a very important matter; that is, pollution of interstate streams. Up to the present time no action has been taken to control this, I believe, except by the individual States or communities interested. In England they have their River Pollution Commissions, which have jurisdiction over certain watersheds, and it seems to me there should be some corresponding federal authority here—whether vested in the Marine Hospital Service, as has been proposed, a National Board of Health or some other body—to act as arbitrator or referee in cases involving the pollution of interstate streams.

The case of the pollution of the Mississippi by the discharge of Chicago's sewage through the Drainage Canal was an example, which resulted in a very costly lawsuit in which the plaintiff, St. Louis, lost the case.

It has been pointed out that bacteria diminish with storage. It is a matter of interest that they also diminish during transportation in a stream. It was found while investigating a new water supply for New Orleans that, although the Mississippi receives the drainage of an immense population, the bacteria have become practically exterminated before reaching that city; so that, although they are to filter the water to remove the mud and silt, the raw water would be quite satisfactory for drinking purposes so far as bacteria are concerned.

A Member.—I would like to ask if Pittsburg has not taken measures to prevent pollution of its water supply?

Mr. Hill.—Pittsburg has at the present time, I think, just about completed a water purification plant, and has been notified by the Pennsylvania State Board of Health that it will be required to provide for sewage disposal in a certain number of years. I do not know what date is set for providing for sewage disposal. Pittsburg, however, forms a very excellent illustration of the endemic condition as differentiated from the epidemic condition. In fact, the endemic condition which is found in Pittsburg is really, from the sanitary standpoint, far more important than that resulting from spasmodic epidemics, and this illustrates very clearly the difference resulting from the urban population as compared with the rural population on a watershed. It has been shown on a number of occasions that the rural population will produce epidemics under favorable conditions, but they are almost universally epidemic, whereas in a situation such as you find in Pittsburg, with a large urban population above the source of supply, you have almost a continuous typhoid fever epidemic.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 50.

PRESENTED SEPTEMBER 22D, 1909.

CONSTRUCTION PROBLEMS OF THE BROOKLYN SUBWAY.

BY JAMES C. MEEM.*

WITH DISCUSSION BY ARTHUR S. TUTTLE AND FREDERICK C. NOBLE.

The Brooklyn Extension of the New York Subway, as designed by the old Rapid Transit Commission of New York and finished by the present Public Service Commission, and as let by contract to the Rapid Transit Subway Construction Company in 1902, probably comprehended in its entirety between City Hall, Manhattan, and Atlantic Avenue, Brooklyn, some of the most interesting engineering problems ever covered by any single contract in the history of our public undertakings.

It is not intended to go into the history or utility of this great undertaking, but merely to describe some of the construction problems in connection with the execution of that part of the contract known as Section No. 3, and also commonly called "The Brooklyn Subway."

As originally designed, this section continued from Section No. 2, on Joralemon Street, just below Clinton Street, with two main tracks and one spur to the station at Borough Hall, two tracks on Fulton Street to Willoughby Street, three tracks to Lawrence Street, two tracks to Flatbush Avenue and three tracks to the end of the contract at Flatbush Avenue and Atlantic, the latter being the easterly end of the Atlantic Avenue Station. Besides the stations at Borough Hall and at Atlantic Avenue, there were two intermediate stations, at Hoyt Street and at Nevins Street.

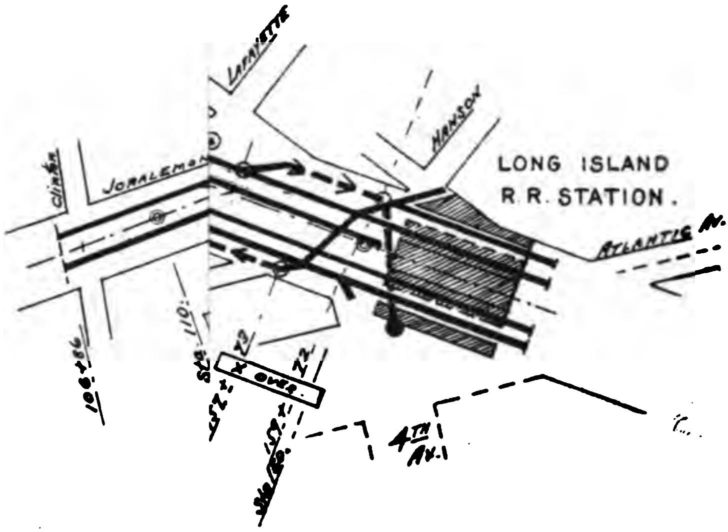
* Chief Engineer, Cranford & McNamee.

Work was begun on this section in April, 1904, by the sub-contractors, Cranford & McNamee, and in the Summer of 1905 something under 1 000 ft. of two-track work had been completed on Fulton Street and an equal amount of three-track work on Flatbush Avenue.

About this period, following agitation in public sentiment, the contract was so modified as to increase the trackage from an average of a little over 2.6 to an average of 4.4 tracks for the entire section. The general plan of this contract as finally modified, adopted and built, is shown on Plate 19, and is described briefly as follows:

Beginning at a point about 70 ft. west of Clinton Street, at the end of the Joralemon Street section of the "Battery Tubes," thence after connecting with these tubes running by separate brick tubes to an intersection with a divided two-track concrete tunnel 300 ft. from Clinton Street, thence for about 100 ft. into a single span, reinforced concrete two-track tunnel, thence by two tracks through the station at Borough Hall, merging into three tracks at the easterly end, and thence into four tracks about Smith Street on Fulton Street, with a depressing track leading north on Fulton Street under the three-track section, to a dead end, for future extensions down Fulton Street. The four tracks continued to Bond Street, where a fifth track began, depressing to the south, merging into a depressed track leading north under the four-track section, for a future extension across Manhattan Bridge. The four main tracks ran thence into five normal tracks at the Nevins Street Station, through which there is, besides these five normal tracks, one depressed track. This latter turns out to the south, after passing the Nevins Street Station, one branch running to a dead end at Lafayette Street and another rising to the normal level at Fourth Avenue. The normal tracks continue to Lafayette Avenue, where a turnout on the east side starts depressing, and finally goes under the normal track, to a dead end at Fourth Avenue. At a point on Flatbush Avenue, between Lafayette Avenue and State Street, there are six full tracks, one of which is depressing and one rising. At Hanson Place there is a normal turnout connection with the Long Island Railroad. The four tracks continue through the Atlantic Avenue Station to a point about 50 ft. beyond. At present, however, two of these tracks are occupied by temporary platforms,

PLATE 19.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.



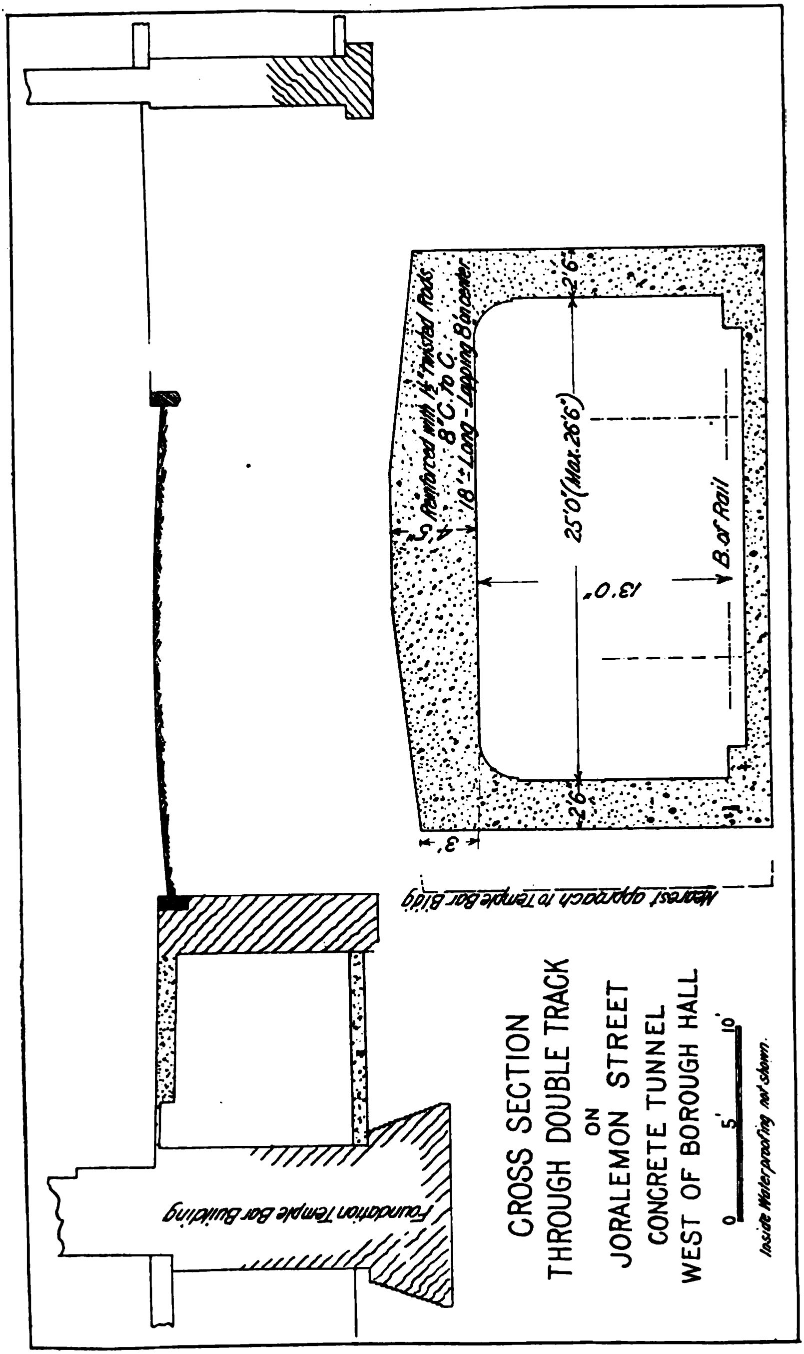

Reinforced with 1½" Twisted Rods. 8" C. to C. 18'± Long - Lapping 8' on center
2'6"
25'0" (Max. 26'6")
13'0"
B. of Rail
2'6"
3'
Nearest approach to Temple Bar Bldg.
Foundation Temple Bar Building
CROSS SECTION
THROUGH DOUBLE TRACK
ON
JORALEMON STREET
CONCRETE TUNNEL
WEST OF BOROUGH HALL
0 5' 10'
Inside Waterproofing not shown.

FIG. 1.—ARCH TIMBERING IN ONE-HALF OF JORALEMON STREET TUNNEL. WEST OF BOROUGH HALL.

FIG. 2.—PARTLY FINISHED SECTION OF DOUBLE TRACK CONCRETE TUNNEL ON JORALEMON STREET. TIMBERING SHOWN IN THE BACKGROUND.

leaving only two tracks for operation. Besides the depressed tracks and turnouts, there are left dead-ended normal turnouts to correspond with the depressed turnouts at Fourth Avenue, Lafayette Avenue, Flatbush Avenue Extension and lower Fulton Street, so that normal and depressed connections can be made at any of these points without disturbing the present subway or its traffic.

A glance at this comprehensive system must convince anyone that it may readily be developed into a gateway or a barrier to the future subway system in Brooklyn.

In addition to the numberless difficulties which the contractor met with in the daily conduct of this work, some of the main problems which confronted him, and which appear to have been successfully carried out, can be summarized as follows:

Building the flat-arched reinforced concrete section in tunnel under Joralemon Street and merging thence into two-track structures of the same material and thence into separated brick tubes; the underpinning of $\frac{6}{10}$ mile of linear frontage of buildings along the route, including one face of Borough Hall, two large department stores on Fulton Street above water level, and a large frontage of important buildings to an elevation below the level of tide water; the underpinning of nearly 1 000 ft. of existing three-track subway, carrying surface tracks and elevated structure; the support of the structures and keeping in active service one mile of street surface lines and one mile of elevated structure and tracks; and the removal and rebuilding of 300 ft. of 15-ft. circular sewer crossing under the elevated structure at Flatbush Avenue, which had previously been built in tunnel; the ordinary problems of maintaining and relaying sewers, water pipes, gas pipes, electric subways and structures, and public service lines of all descriptions, and of maintaining the organization with which it was necessary to do this work safely and satisfactorily; and lastly to meet and rebut such complaints as the good people and the press of the favored borough were wont to make daily and hourly.

Without lengthening this paper or going into minute details, an attempt will be made to describe briefly the engineering features of some of the problems presented. Reinforced concrete was used almost exclusively, except at the stations, double-decked structures,

under the elevateds and at three-tracked turnouts. In order to set at rest the qualms of those who may fear that reinforced concrete is more difficult to build than all-steel, it may be stated parenthetically, that by the building of the roof and side walls in alternating sections between existing bents of timber, results were obtained which appeared to be entirely satisfactory. The tunnel section began at the west of Borough Hall and continued as noted, by a 26-ft. span of flat roof reinforced concrete arch for 200 ft.; thence with a middle wall for 100 ft. more; thence into two circular brick tubes with 16-in. (4 rings) brickwork and without haunch walls. The north wall of the first section noted passed within 11 ft. of the edge of the foundation of the Temple Bar Building, a ten-story modern office building, while the sub-grade of the structure was about 13 ft. below the bottom of the foundations of this building. The system used was the sectional shield method, starting with the ten sections or "jills" set flat, and finally at the brick tubes developing into two sets of five each, conforming to the extrados of the arch at these points. These were followed by the arch timber system of bracing with five segments set on the wall plates at the springing line of the tunnel. Double sets were used in the concrete section, as shown on Plate 22, and one set each in the brick sections. The system of longitudinal tie-bracing was used, consisting of overlapping channels bolted back to back, below which sheeted trenches were dug and sections of bottom were built, on which the roof-supporting timbers were placed pending the excavation and construction of the remaining portion of the work. Extraordinary care was used in passing the Temple Bar Building and the sides were shored with horizontal 2-in. boards set in mortar and grouted behind to fill all voids. The general type of bracing used in all the rest of the work, which was in cut and cover, was an adaptation of this method without the heading system, consisting of cross-bracing and longitudinal ties, as shown on Plate 24. The surface tracks were first underlaid with I-beams generally 22 ft. long, to cover four 5-ft. bents of steel, or two 10-ft. bents of timber. The work then proceeded generally as in tunnel work, the excavation being handled from the headings and hauled back to the shafts by mule-cars, where it was hoisted by derricks and loaded on the cars, furnished by special arrangement with the Brooklyn Rapid Transit Company, on tracks laid on sidings for that purpose.

PLATE 22.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.

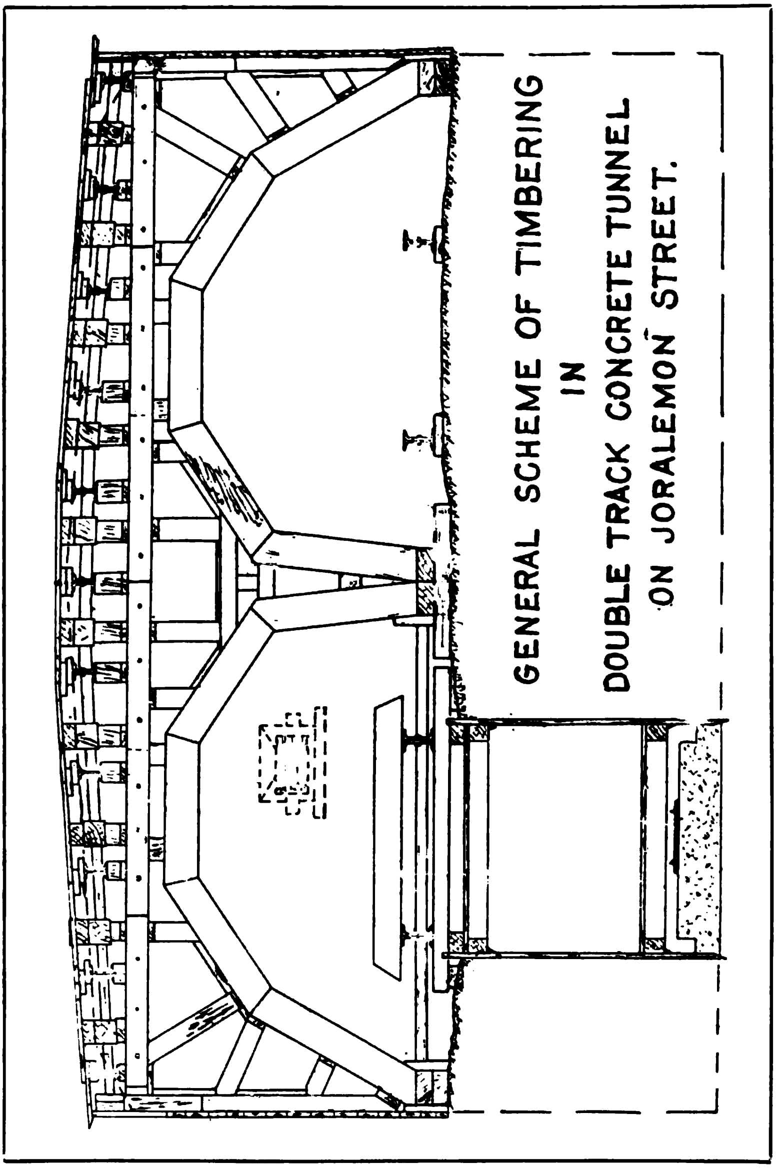
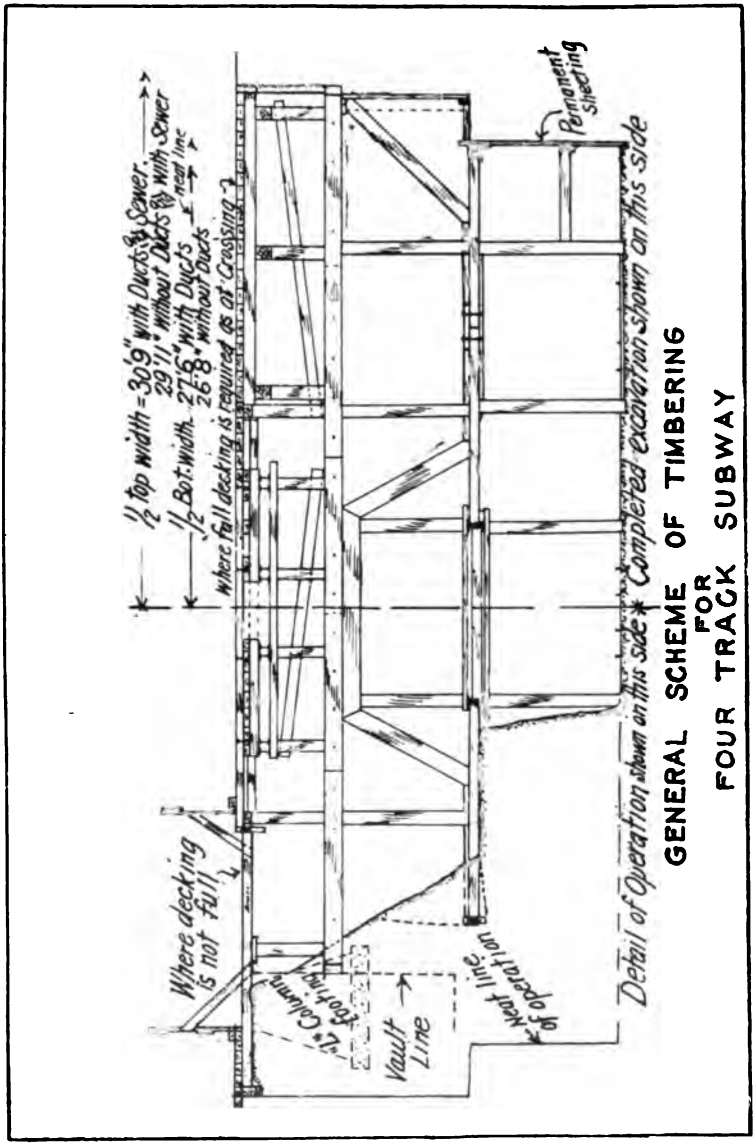


FIG. 1.—SUBSURFACE OBSTRUCTIONS MET WITH AT COURT AND JORALEMON STREETS.

FIG. 2.—TYPE OF ELEVATED COLUMN SUPPORT ON FLATBUSH AVENUE, WITH FOUNDATION REMOVED FROM COLUMN.

PLATE 24.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.



GENERAL SCHEME OF TIMBERING FOR FOUR TRACK SUBWAY

The underpinning of so large a linear frontage of buildings presented an interesting problem. In almost every instance these buildings were carried on isolated piers. In the underpinning each separate pier was carried on I-beams or girders cut into the piers and maintained on temporary blocking sufficiently far away from the area required for the pit, not to endanger the structure. These pits were box-sheeted, mortar and grout being used to fill all voids as the work progressed. Where there was no water, the pits were filled with concrete as soon as sufficient depth had been reached, and after this concrete had set the space between the top of the concrete and bottom of the pier was either bricked in and shimmed, or grouted, the needle-beams removed and the spaces occupied by them again bricked up. Where the requisite depth of pit was below the normal level of the water, piles were driven in the pits. These piles were either hollow pipe or steel pile coffer-dams. They were cleaned out as soon as driven, as to the sand, leaving the water in place to prevent influx of sand from the outside, after which they were concreted and the work of underpinning carried on as previously described.

In the existing three-track structure already completed for about 1 000 ft. in Flatbush Avenue, pits, 6 ft. square, similar to those described, were sunk 15 ft. apart in the middle of the existing tracks in the old subway, and on these trusses were erected, as shown on Plate 28. These trusses sprang from three 20-in. 80-lb. I-beams, 15 ft. long between pits. The various types shown on Plate 28 were required by the position of the depressed track, whether it was wholly or partly under the existing structure. The footing of each pit penetrated about 4 ft. into water, and rested on concrete and steel pile coffer-dams generally 4 ft. square. Although the surrounding earth was subsequently excavated to within 18 in. of the bottoms of these piles, no settlement of these footings was noted.

In the elevated road, of which there are two types, the Fifth Avenue "L" with channel columns having flared heads, and the Fulton Street "L" type with Phœnix columns, the former were supported with the type of bracing shown on Plate 23, Fig. 2. Pits, 5 ft. square and 10 ft. horizontally from the centre of each column (or as near that as was expedient under the conditions), were first sunk to below sub-grade; sills were placed and from these up-

rights reaching to cross-caps at the surface were set up. These uprights were intended to be and were subsequently incorporated into the general system of bracing. From these, A-frames were sprung, the top being filled in with grillage. Eye-bars usually 3 in. by ¾ in. in sets were used as tension members, the whole arrangement being clearly shown in the illustrations. As to the Phœnix columns, it was found necessary to design a special collar, which was bolted and blocked up to the head of the column at the cross-girders, to transfer a portion of the weight of the latter to the outside frame which supported the column. The tops of the inside A-frame were separated by hard wood blocking, and carried caps directly supporting the cross-girders just inside of the column. Eye-bars were also used in this construction to form the tension members of the truss. The arrangement of these A-frames is clearly shown on Plate 25, Fig. 1.

The rebuilding of the 15-ft. sewer at Hanson Place involved the reconstruction of some 50 ft. of reinforced concrete construction, and the rebuilding of about 250 ft. more, partly in reinforced concrete and partly in brick work. In order that there might be no danger to the other work due to the flooding of this sewer, which sometimes ran under an excessive head (sufficient to blow off manhole covers), it was decided to do this work previous to the general construction. The elevated columns were first supported over the area affected, some of the timber footings being cut through the existing sewer. The open-cut work was then carried forward by ordinary methods. That portion of the sewer to be reconstructed was first underpinned and a new invert built in a manner somewhat similar to that by which portions of the "Battery Tubes" were reconstructed with concrete inverts. Plate 29 shows this work in progress with the 48-in. by-pass for taking care of the temporary flow of sewage. Special care had to be exercised in cutting through the old in order to join the new work at the connection between the reconstructed and rebuilt portions of this work. It was very interesting to note the condition of the materials originally used in building this sewer, which was constructed by the Anderson and Barr "Pilot System." The plates used in this construction were found to be in excellent condition and some of the barrel staves used as poling-boards in poling out to erect these plates, were also found to

PLATE 25.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.

FIG. 1.—GENERAL VIEW OF FULTON STREET, LOOKING EAST AT FLATBUSH AVENUE. AT THIS POINT THERE ARE FIVE TIERS OF STANDARD GAGE RAILWAY TRAFFIC, INCLUDING TWO ELEVATED AND TWO DEPRESSED TIERS.

FIG. 2.—STANDARD TIMBERING ON FLATBUSH AVENUE, FOR SIX-TRACK SUBWAY.

PLATE 26.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.

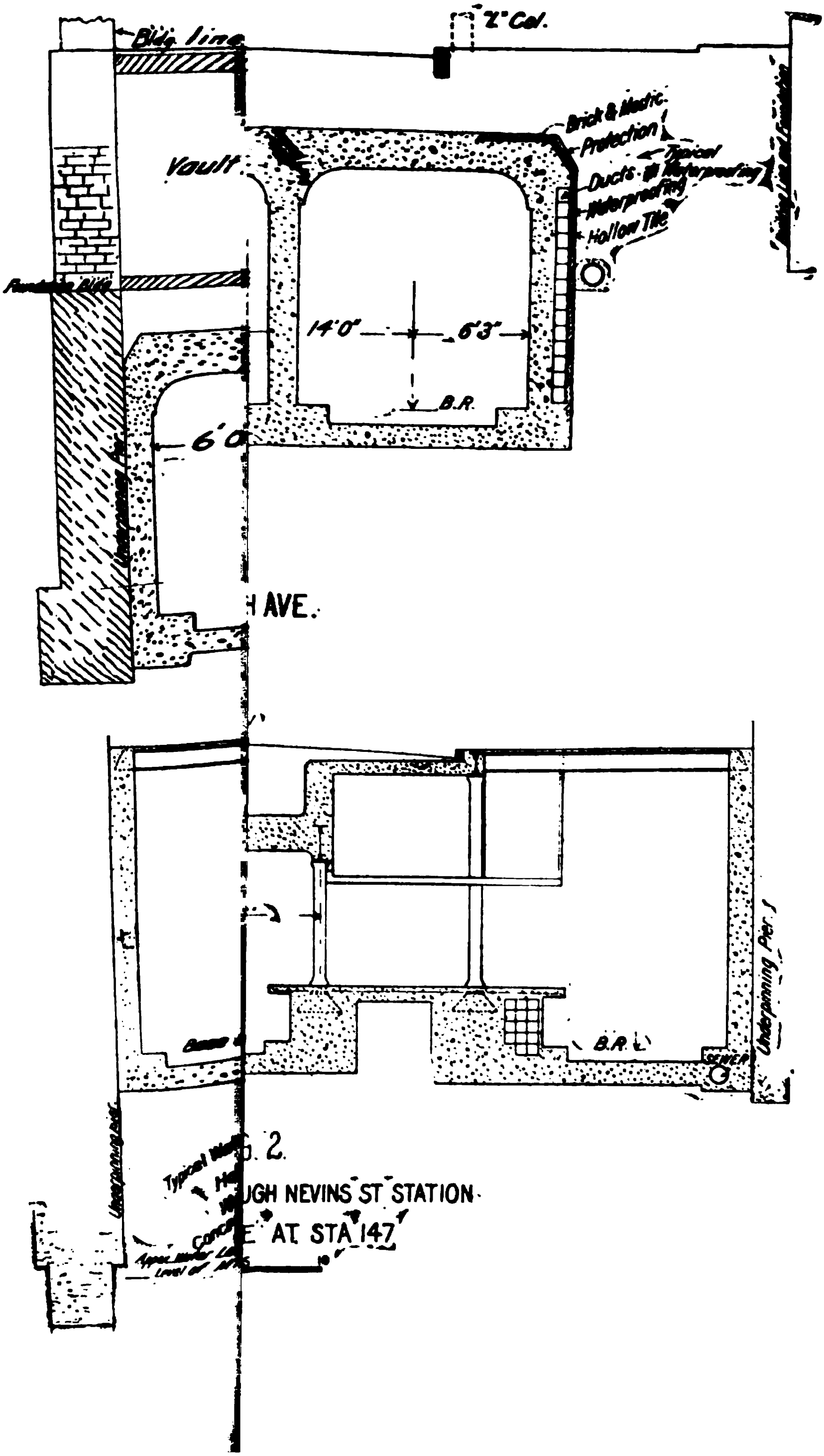
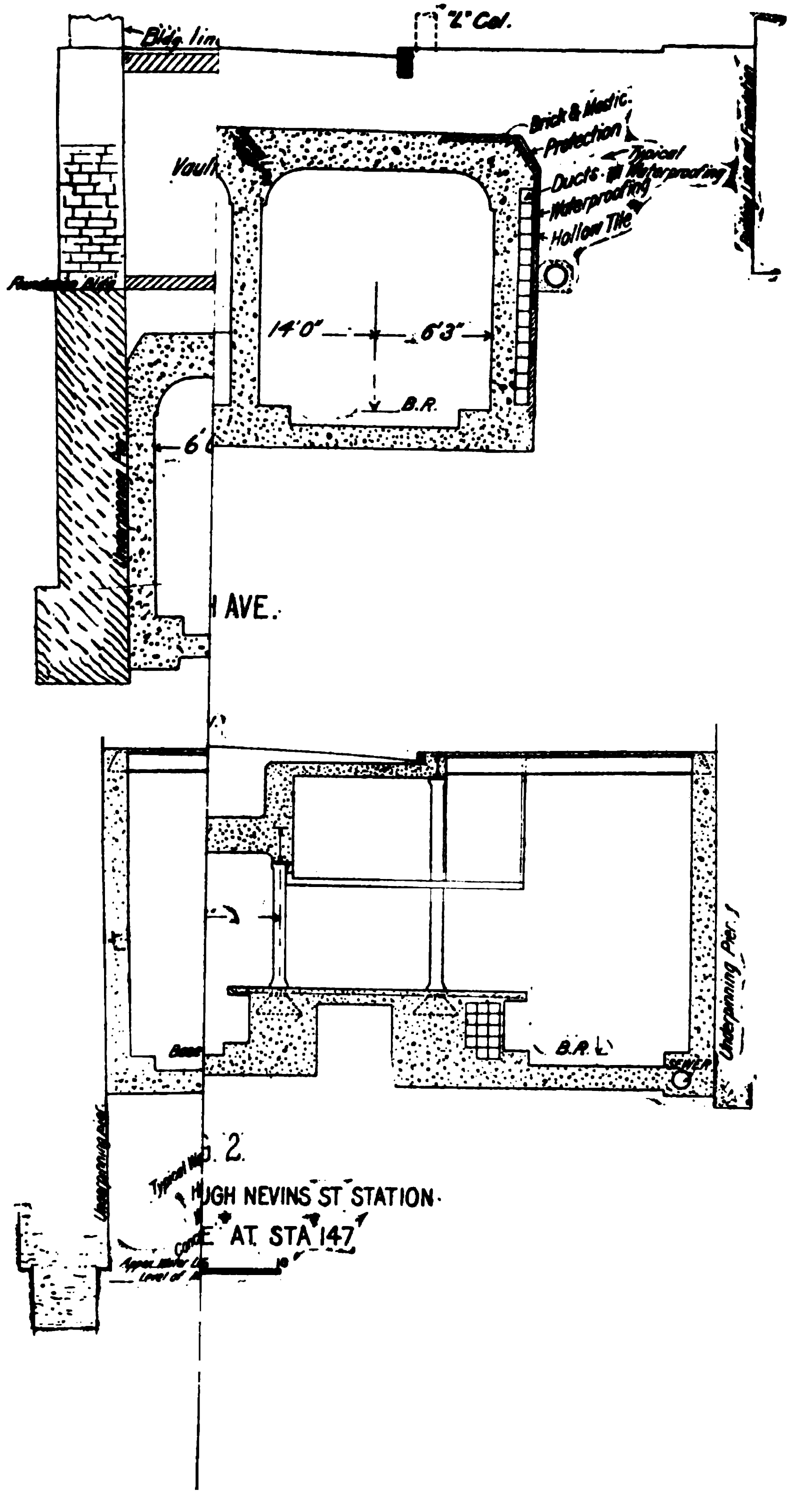


PLATE 26.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.



...G. 2.
...UGH NEVINS ST STATION
...E AT STA 147

STANDARD AND DEPRESSED TRACKS IN FULTON STREET, APPROACHING BOROUGH HALL FROM THE EAST.

be in good condition, as well as the stiffening boards used in building the sides and bottom below the plates. As this sewer was built in 1893, the material had been in the ground about 15 years.

The entire section comprised in this sub-contract was about 5 800 lin. ft., centre line measurement, with an average, as previously stated, of 4.4 tracks, making a total of approximately 25 000 ft. of single track. It was begun, as stated, in April, 1904, and the trains were in operation May 1, 1908. The elapsed time included, of course, a large amount of delay necessitated by the change in plan which covered the redesigning and reordering of the steel for this very much more elaborate and intricate structure. The work was done for the Rapid Transit Subway Construction Company, under the direction of the engineers of the Rapid Transit and Public Service Commissions and was built by the sub-contractors, Cranford & McNamee of Brooklyn.

The writer is indebted to Mr. Frederick C. Noble, M. M. E. N. Y., Division Engineer for the Public Service Commission, Mr. George H. Pegram, Chief Engineer of the Rapid Transit Subway Construction Company, and Mr. F. L. Cranford of Cranford & McNamee, for the use of photographs, data and material used in this paper.

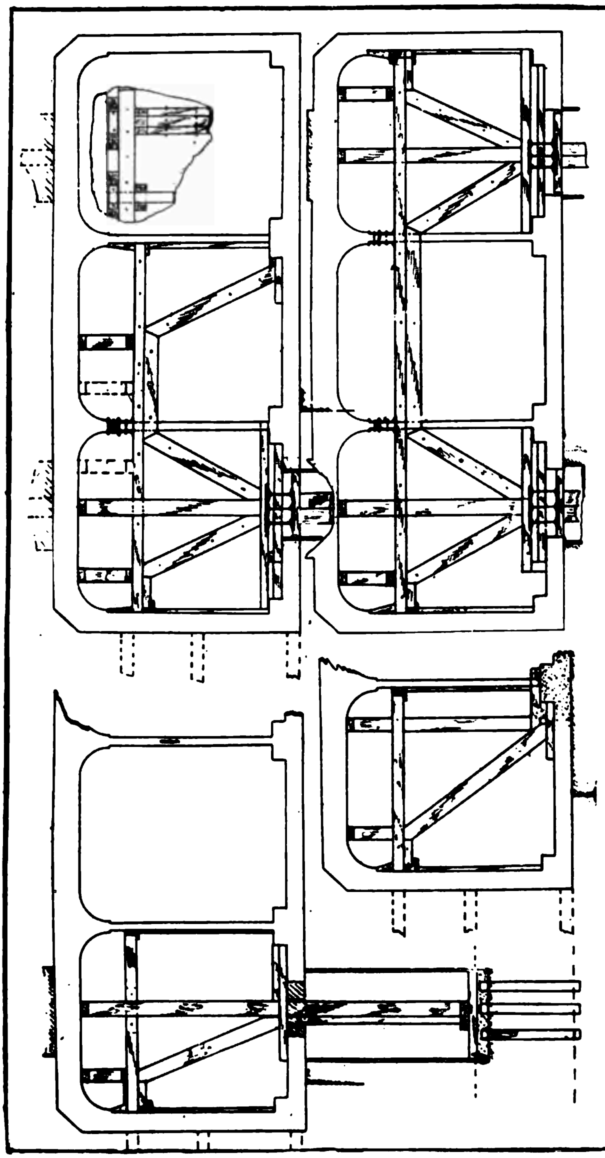
DISCUSSION.

MR. ARTHUR S. TUTTLE.—I am sure we all feel indebted to Mr. Meem for the interesting description which he has given us of the work with which he has been so intimately connected. A considerable number of our members are engaged in undertakings of a similar nature, and I trust that the paper will be thoroughly discussed and that every member will feel entirely free to question Mr. Meem concerning any points upon which further information is desired.

MR. FREDERICK C. NOBLE.—Besides supporting nearly a mile of elevated railroad structure, the contractor underpinned more than a half mile of building frontage. Because of the peculiar conditions it was incompatible with a proper regard for the safety of the public to carry on the work entirely under cover so as to leave the surface unobstructed. A bitter campaign to force this method was waged unsuccessfully, in the newspapers, by a number of selfish merchants and others, and it is no doubt on this account that the false impression exists that the work was unduly slow. It will therefore surprise many to learn that the progress in proportion to trackage, from the beginning of construction to complete operation, was one-third more rapid than the corresponding mean progress on the open cut sections of the Manhattan subway. Only two sections, where much simpler conditions existed, made better records in this respect. In this comparison no allowance is made for delay caused by the radical change of plan after construction began.

The author of the paper modestly omits to mention that the special methods he describes were mainly devised by himself. Their successful working was due to his unremitting efforts as well as to their own merit.

PLATE 28.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MEEM ON CONSTRUCTION PROBLEMS
OF THE BROOKLYN SUBWAY.



VARYING TYPES OF TIMBERING USED IN UNDERPINNING.
EXISTING THREE TRACK SUBWAY ON FLATBUSH AVE

RECONSTRUCTION OF 15-FT. GREENE AVENUE SEWER AT FLATBUSH AVENUE AND HANSON PLACE.

valley too deep to be passed by aqueduct at the hydraulic gradient on embankment: (1) Steel pipe; (2) reinforced concrete pipe; (3) pressure tunnel. The reinforced concrete pipe, in the present state of the art, is certainly not economical for a head above 125 ft., and tests have caused it to be generally limited in the work of the Board of Water Supply to heads less than 50 ft.* It is, hence, not available for the more important valleys which require heads several times as great, reaching 400 ft. in the case of the Hudson river crossing. The pressure tunnel (a designation coined by the engineers of the Board of Water Supply, for tunnels subjected to unbalanced internal heads), has not been used for such high heads as those met in the Catskill Aqueduct. The evidence of the suitability of the type is given later in the paper.

The steel pipe is always in competition with the pressure tunnel, and so close are the figures that it will never be known whether the pressure tunnel built, or the steel pipe that might have been built, was really the more economical for the various valleys crossed by pressure tunnels. This uncertainty is due, also, in large measure, to the fact that the steel pipe siphons, assumed, as they were, to consist of three or four large pipes about 9 ft. to 11 ft. in diameter, could be installed in parts as the consumption increased, so that the present cost of the deferred installations was materially less than the cost unreduced, and, on the other hand, the steel pipe was assumed to be of finite life, so that a fund for perpetual renewal had to be added to first cost. All this complicated the comparison, making such matters as rates of interest of paramount importance. Appendix 1 shows a summary of a typical steel pipe estimate.

Where the geological conditions were favorable, the pressure tunnel was chosen, even if of slightly greater cost, because it is believed to require little or no maintenance.

An outline of the method of fixing slopes and hence sizes of the various types of aqueduct, including pressure tunnel, will be of interest.

When the problem was attacked in the spring of 1906, the

*A revolution in aqueduct location would occur if the art of making reinforced concrete aqueduct improved greatly, as would occur if steel of higher modulus of elasticity were invented, or means invented for making the strength of the steel available without cracking the concrete. Then the locating engineer would have to study locations within the zone between the hydraulic gradient and a plane at a distance below the gradient dependent on the maximum head permissible for reinforced concrete pipes.

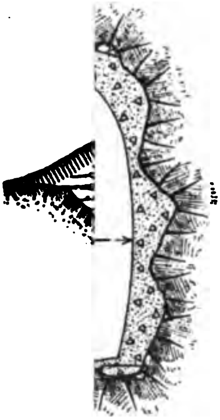
location of the aqueduct was not known closer, as it turned out, than within a zone about 8 miles wide (measured perpendicular to a straight line from Ashokan Reservoir to Hill View Reservoir), at Ashokan Reservoir, 15 miles wide in the vicinity of the Hudson River and 6 miles wide in the vicinity of the proposed filter plant near White Plains. The Rondout Valley had been partially explored by borings, so as to indicate that a shallower tunnel could be obtained on a line from Olive Bridge Dam than on a line from the easterly end of Ashokan Reservoir. The outlet elevation at the Ashokan Reservoir had not been determined, hence the hydraulic gradient was not fixed at the north end. It was known that cut-and-cover aqueduct and grade tunnel would be used, but it was not known whether valleys would be crossed by pressure tunnels entirely, by steel pipes entirely, by one or the other of these types with reinforced concrete pipes for the shallower valleys, or by other combinations of these three types of siphon. It was known within 10 ft. what total fall was available from Ashokan Reservoir to Kensico Reservoir, but it was not known at what rate the resulting slope would be most economically distributed between the various types of aqueduct. The following steps were taken:

1. The economic outlet elevation at Ashokan Reservoir was determined by assuming a probable line of aqueduct and changing the assumed outlet elevation until the decreased cost of the aqueduct due to steepening the average gradient was computed as equal to the cost of replacing, by increasing the height of dams, dikes, etc., in the reservoir, the storage rendered unavailable with the higher outlet elevation.

2. The cost of a line having the most economical relation between slopes (see Appendix 2) of the various types of aqueduct was computed for each of two routes, assuming first that all the siphons were steel pipe except a few shallow ones of reinforced concrete; and second, that all the siphons were pressure tunnel except the same shallow reinforced concrete siphons and a few where steel pipe seemed obviously indicated.

From this set of computations it was concluded to start the aqueduct from near the Olive Bridge Dam instead of from the West Hurley or eastern end of the Ashokan Reservoir; that if sound rock were generally within 100 or 200 ft. of the surface of

PLATE 32.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS



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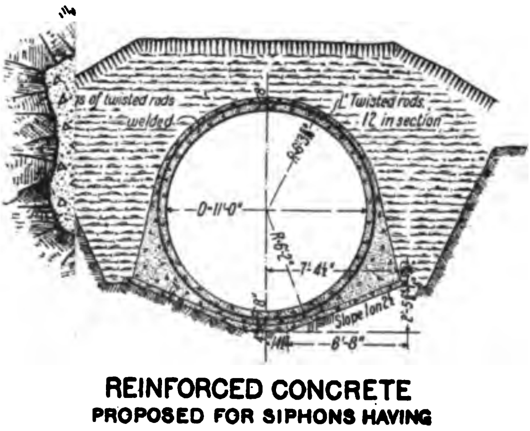
City of New York
BOARD OF WATER SUPPLY
TYPES OF CATSKILL AQUEDUCT
Other sizes than those given for the various types are used in some parts of the aqueduct

2 0 2 4 6 8 10Ft.

OCTOBER 27, 1909



REINFORCED CONCRETE
PROPOSED FOR SIPHONS HAVING
HEADS 125' OR LESS - NOT USED

Drawn
Traced
Checked

the ground, pressure tunnels promised generally to be more economical than steel pipes; and also, by subsidiary computations, that very little economy was sacrificed by fixing the same slope for steel pipes and pressure tunnel; so that either type could be inserted at a later date and the necessary postponement, until the borings were completed, of the decision as to which type to use at any siphon would not prevent locating most of the aqueduct and getting under construction those portions which were to be at the hydraulic gradient.

It was also evident from subsequent computations that the length of aqueduct line and the proportion of various types did not vary much between all locations thought practicable, including lines crossing the Hudson River at different points from Peggs Point to below West Point.

The slopes and sizes established for the different types for the aqueduct between Ashokan and Kensico Reservoirs were as follows:

SIZES AND SLOPES OF AQUEDUCT, ASHOKAN RESERVOIR TO KENSICO RESERVOIR (SIPHON SIZES PRELIMINARY).

Type of Aqueduct.	Relative Coefficient in Chezy Formula.	Slope.	Size.
Cut and cover.............	125	0.00021	17 ft. high by 17 ft. 6 in.
Grade tunnel..............	120	0.00037	17 " " " 13 " 4 "
Pressure tunnel...........	120	0.00059	14 " 6 in.
Steel pipe................	96	0.00059	4 lines 9 ft.

Gross allowance in head for Hudson River siphon to provide for any contingency, 7 ft.

The cut-and-cover and grade tunnel slopes were fixed exactly and finally by these first figures, done in less than two months in the spring of 1906. The slopes of siphons were intended to be slightly elastic to permit adjustment in length, and have been slightly modified in most cases. Three mortar-lined and concrete-covered pipes were substituted finally for the 4 lines above listed.

With these assumptions the first contract was let for cut-and-cover and grade tunnel aqueduct extending over a stretch 12.8 miles long east of the Hudson River, from east of Cold Spring to southeast of Peekskill, except that gaps were left for three siphons aggregating about 2.1 miles. At this time it was hoped that

geological conditions would be found favorable for pressure tunnel in the majority of the siphons which were expected between Ashokan and Hill View Reservoirs. The geological investigation and the economic comparisons are now completed, except at the Hudson River, with the following result:

CATSKILL AQUEDUCT.

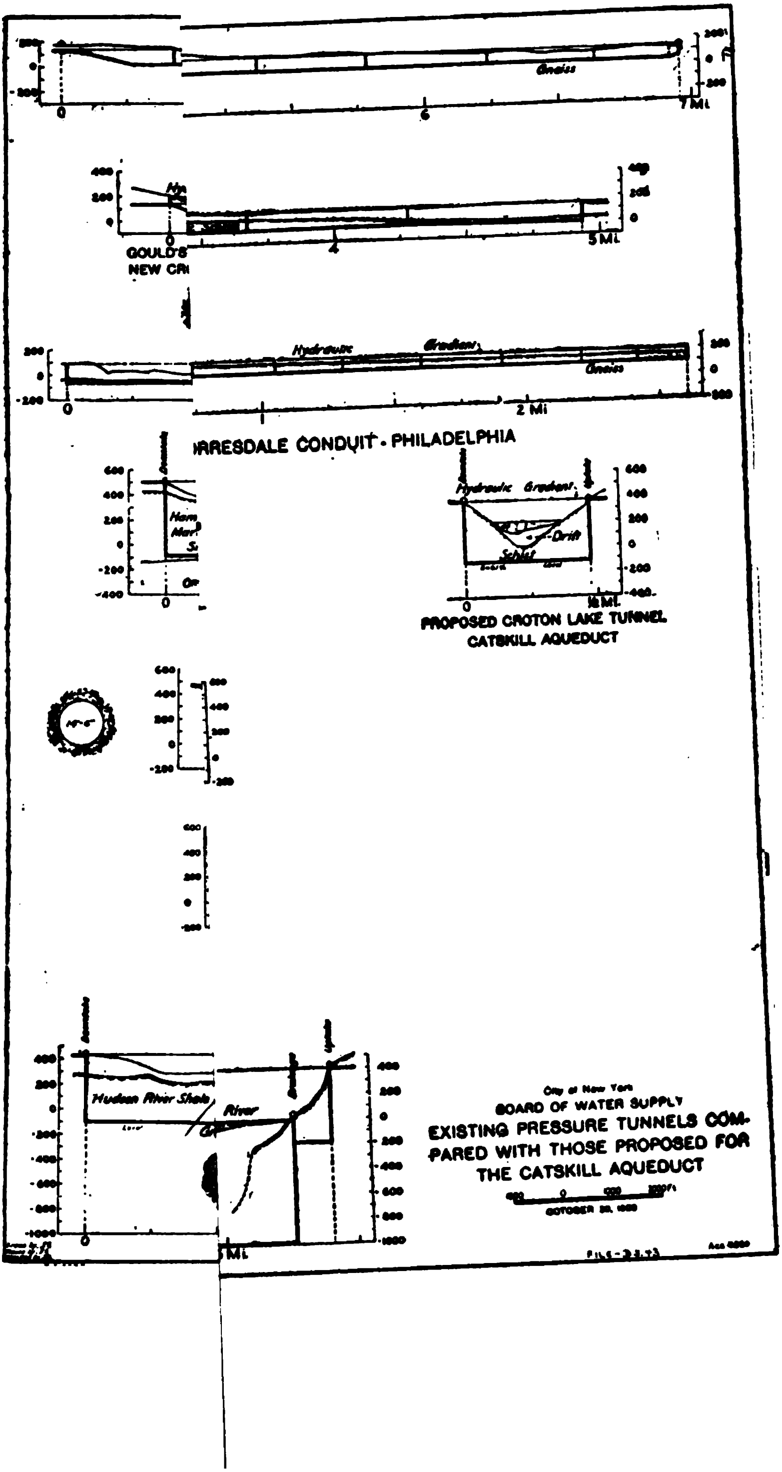
Lengths of siphons, arranged in geographical order from Ashokan Reservoir to Hill View Reservoir.

Name.	LENGTH OF SIPHON, IN FEET.					
	Steel Pipe.		Pressure Tunnel.			
	Projected length.	Developed length.	Horizontal length between c.l end shafts.	Downtake shaft.	Uptake shaft.	Total waterway.
Esopus	2 091	2 117	....	....	....	....
Tongore	680	708	....	....	....	....
Rondout	....	....	23 608	571	675	24 854
Wallkill	....	....	23 891	459	898	24 248
Washington Square	3 275	3 289	....	....	....	....
Moodna	....	....	25 200	572	—	25 772
Hudson River (Assumed lowest elevation, — 1 350)	....	....	3 786	1 165	1 709	6 660
Foundry Brook	3 747	3 788	....	....	....	....
Indian Brook	593	617	....	....	....	....
Sprout Brook	2 157	2 234	....	....	....	....
Peekskill	6 588	6 681	....	....	....	....
Hunter's Brook	1 477	1 482	....	....	....	....
Turkey Mountain	1 534	1 544	....	....	....	....
Croton Lake	....	....	2 639	508	493	3 640
Harlem Railroad	725	736	....	....	....	....
Kensico	1 630	1 641	....	....	....	....
Elmsford	1 485	1 500	....	....	....	....
Fort Hill	1 265	1 280	....	....	....	....
Bryn Mawr	5 990	6 018	....	....	....	....
Yonkers	....	....	11 800	....	128	11 928
Total lengths north of Hill View Res.	33 237	33 630*	90 424	3 270	3 [illegible]08	97 102
City Siphons	....	84 000	....	....	....	93 000

* Ultimately 3 lines each totaling to this.

It will be seen from the above table that steel pipes were found generally more economical for the shorter siphons. This is because the sound rock is so deep, either actually or relatively to the width of the valley, that the pressure tunnel waterway would have been greatly lengthened by the two deep end shafts. These shafts are much more expensive than the tunnels, so that the pressure tunnel was badly handicapped in the competition both in length and

PLATE 33.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



in increased proportion of the most expensive type which goes to make up that length. As an illustration, the case at Rondout siphon may be compared with that at Sprout Brook siphon.

TABLE ILLUSTRATING UN-ECONOMY OF PRESSURE TUNNEL FOR DEEP, NARROW VALLEYS.

	Sprout Brook Siphon.	Rondout Siphon.
Horizontal length of pressure tunnel	2 230	23 610
Total length of waterway shafts	1 250	1 260
Total length of whole waterway	3 480	24 870
Proportion of total waterway which is in shafts	36%	5%
Length of steel pipe	2 260	23 700
Excess of total length of waterway of tunnel, expressed as proportion of length of steel pipe	50%	5%

N. B.—Sound rock at Sprout Brook is comparatively deep, but result would still be very unfavorable to pressure tunnel if sound rock were near surface.

Another handicap which the pressure tunnel suffers in such cases is that the tunnel is relatively expensive, not only due to its length but also because it must be larger, relatively, to use only the same amount of the total fall of the aqueduct. No economic comparisons are pertinent which do not provide for the same drop in head in the aqueduct, for the using up of drop in head in one link requires compensating allowances in head and hence in size and cost of the other links.

This preliminary explanation being completed, long but rather necessary to show the reason for the existence of the pressure tunnel and its relation to the rest of the aqueduct, the pressure tunnel alone will occupy the balance of this paper.

EXISTING PRESSURE TUNNELS.

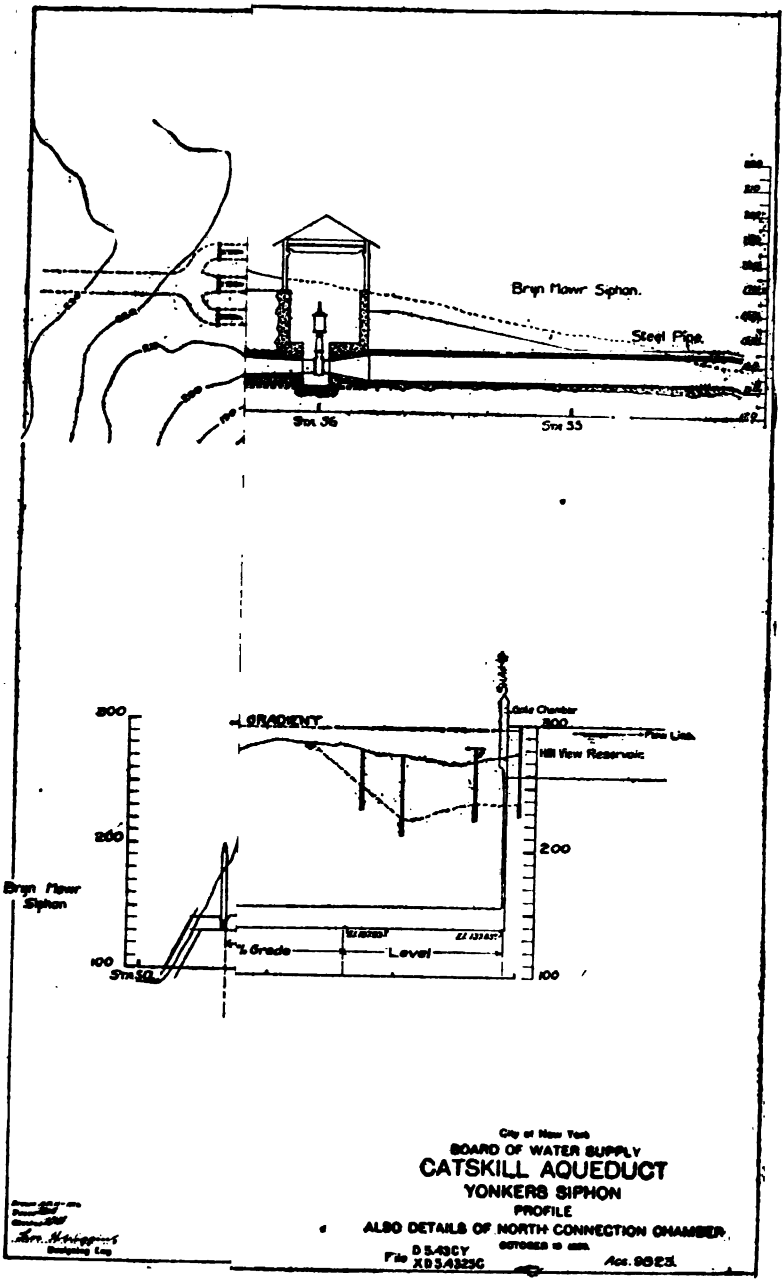
Plate 33 shows the principal existing pressure tunnels and those being built or proposed for the Catskill Aqueduct. It will be at once evident that there is little precedent for pressure tunnels in which the hydraulic gradient stands much above the surface of the ground. Many tunnels other than pressure, and mines extending

under lakes, rivers and oceans furnish examples of the tightness of rock against heavy inward pressure, and it is but a short step in inference that the same tunnels and mine drifts, and similarly pressure tunnels under substantial cover of sound rock, would endure heavy *outward* pressure with a negligible amount of leakage. Appendix 3 gives a list of the most pertinent tunnels, pressure or other, driven under bodies of water without the use of compressed air and of certain mines under bodies of water. The principal points of interest in the more important existing pressure tunnels are as follows:

New Croton Aqueduct.—The greater part of this aqueduct is tunnel at the hydraulic gradient, but a short stretch under Gould's swamp, near Tarrytown, and a stretch of about 7 miles at the lower end is tunnel generally about 100 ft. below the hydraulic gradient, with a stretch about 1 250 ft. long under the Harlem River that is slightly more than 400 ft. below the gradient. This latter stretch is the only one where the gradient is more than 40 ft. above the ground, the gradient being here about 135 ft. above the surface of the Harlem River. Generally the gradient is below the ground. Of existing tunnels known to the writer the Harlem River siphon is the nearest approach to the pressure tunnels proposed for the Board of Water Supply work, and it is a satisfactory and convincing precedent. The Croton pressure tunnel is built of rubble masonry, concrete and brick of the sections shown on Plate 33. Natural cement was used. The rock is mainly Manhattan schist and Fordham gneiss with some Inwood limestone, a band of the latter, about 700 ft. wide, existing at the Harlem River Crossing. The outward leakage in the 7 miles of pressure tunnel was reported as 225 000 gal. daily or at the rate of 32 000 gal. per mile daily. The tunnel was grouted over the arch.

Torresdale Conduit.—This conduit connects the Torresdale Filter plant of the City of Philadelphia with the Lardner's Point Pumping Station, where the filtered water is lifted into the distribution system. The tunnel is in gneiss of a rather poor quality, the rock cover being about 75 ft., the total cover about 100 ft. and the hydraulic gradient being at about ground level. The finished diameter is 10½ ft. and the lining consists of 12 in. of brick work, outside of which is concrete. The inward leakage, after lining,

PLATE 34.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS



in 14 000 ± ft. of tunnel was about 1½ million gallons daily, and this was not materially reduced by grouting. The grout circulated in the rock all right, but most of it (as determined by measuring material removed when cleaning up) came out through the many leaks. The ground-water head acting inward is about the same as the filtered water head acting outward; hence, in use there is little tendency to leakage. The Chief Engineer, Mr. John W. Hill, under whom the plans were drawn and the tunnel constructed, stated that they did not regard perfect tightness as essential under the circumstances. The grouting was done under Mr. Hill's successor.

Cincinnati Land Tunnel.—This tunnel, constructed under Mr. G. Bouscaren, Chief Engineer, is about 22 250 ft. long and 7 ft. in finished diameter. It is lined with 8½ in. of exceptionally hard-burned shale brick (absorption about ½% in 48 hr.) laid with ¼-in. to ⅜-in. joints in 1:2 Portland cement mortar. This lining is backed with 1:2:4 concrete having a minimum thickness of about 4 in. and an average of about 8 in. The hydraulic gradient is generally about 45 ft., with a maximum of about 85 ft. above the ground, about 155 ft. above the tunnel arch and about 90 ft. above low water in the Ohio River, along which, within 300 to 1 000 ft., the tunnel runs. At one point the total cover is only about 70 ft., and 1 000 ft. of tunnel at and adjacent to this place is reinforced by steel hoops having a cross-section 1½ in. by $\frac{5}{16}$ in., spaced 24 in. on centers and placed between the brick and concrete. These were used because the dead weight of the material overlying the tunnel did not equal, area for area, the unbalanced upward water pressure. The rock consists of interbedded limestone and shale in approximate horizontal strata from a few inches to 2 ft. thick. The rock was dry and tight except for about 5% of the tunnel. The rock cover is generally only about 20 ft. and the total cover about 110 ft. This tunnel is a model of workmanship and tests show an outward leakage of only 60 gal. per minute in the whole 22 250 ft. of tunnel, with a head of 85 ft. above the river level at the time. The leakage inward, with the river about 75 ft. above the tunnel, varied from 10 gal. per minute for the first test to 14 and 17 gal. per minute respectively for two subsequent tests 5 and 8½ months after the first test.

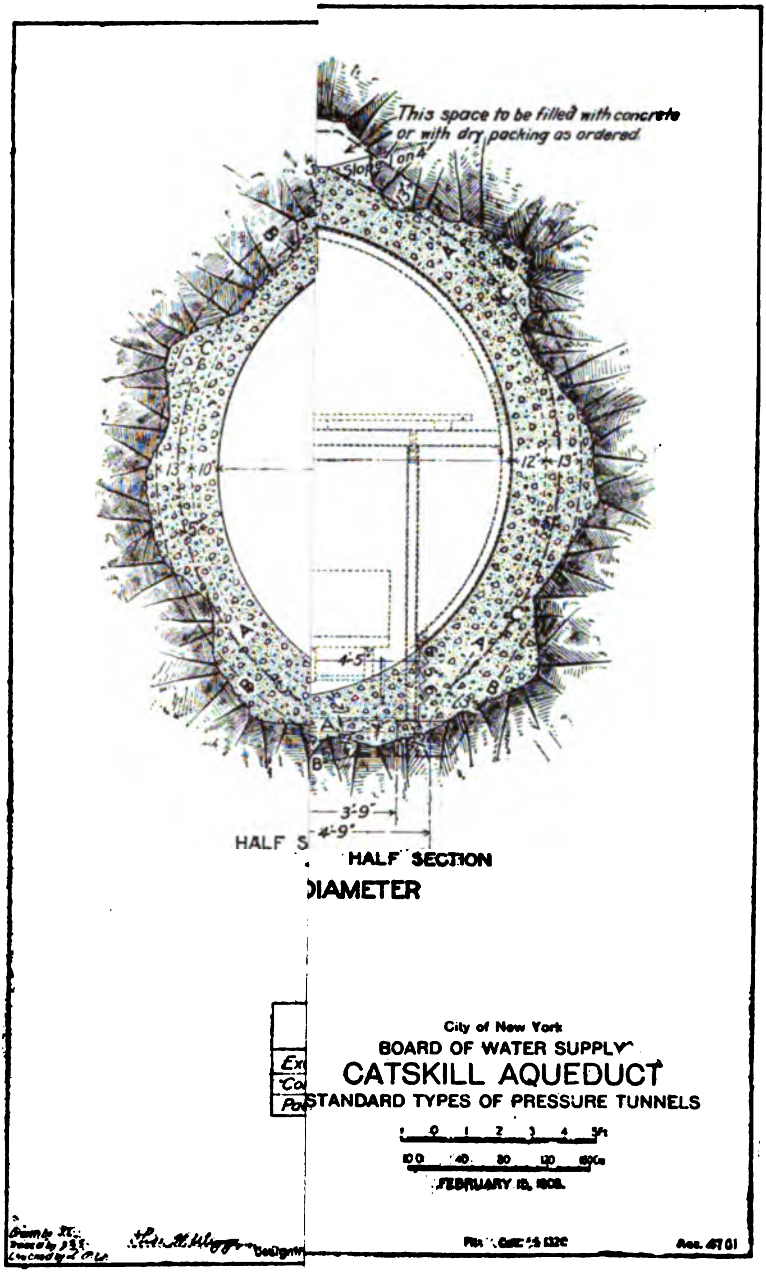
Washington Aqueduct Tunnel.—This tunnel is about 5 miles long and of horse-shoe section 9 ft. 10½ in. wide. Its construction was closely modeled after the Croton Tunnel which preceded it by a few years. It is in micaceous and hornblendic schists with a rock cover of from about 20 to 120 ft. and a total cover including earth of about 50 to 160 ft. The hydraulic gradient is generally at or below the ground surface, but in one stretch about a mile long the gradient is from 0 at the ends to about 110 ft. above the ground, and this maximum occurs where the rock cover is only 30 and the total cover only 50 ft. The original profile of the tunnel contained several summits, which were eliminated by increasing the height of the tunnel where necessary. This makes in places high vertical side walls which have had to be braced against external pressure by metal columns. This tunnel is pumped out every year or so. No record of leakage has been found, but leakage cannot be excessive.

CATSKILL AQUEDUCT PRESSURE TUNNELS.

Rondout Siphon.—The geology of this siphon and the others has been discussed in a previous paper before this Society* and will be recalled here only in outline. Note the broad foldings, the thick strata of Marcellus and Esopus shales, limestones and Shawangunk grit, the two latter separated by comparatively thin beds of Binnewater sandstone and High Falls shale, and the whole lying non-conformably on the unmeasured bed of Hudson River shale. The shales and most of the limestones are compact and dry, being sufficiently weak to re-form themselves, when folded, without having fissures. The grit is hard and brittle and has crevices on the convex side of the folds due to its resistant nature. It is generally water-bearing and the water has a trace of hydrogen sulphide due to a little pyrite in the rock. The Binnewater sandstone is honeycombed, due to solution of secondary minerals, and hence water-bearing to an unusual degree. The shaft through this material has caused much trouble due to water, and grouting has been done successfully to reduce the flow, which has been as much as 1 000 gal. per minute. The tunnel profile was fixed by several conditions:

* Paper No. 89, by Messrs. Mallett, Ridgway, W. F Smith and Spear, of the Board of Water Supply, entitled "Subsurface Investigations of the Board of Water Supply for the Proposed Catskill and Long Island Aqueducts and Reservoirs," published in 1908 *Proceedings.*

PLATE 35.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



(*a*) To mostly avoid the grit at Station 700; (*b*) to avoid the High Falls shale at Sta. 615±; (*c*) to pass quickly through the Binnewater sandstone and High Falls shale at Sta. 600; (*d*) To get safely under the buried gorge at Sta. 500; (*e*) to avoid driving downhill; (*f*) to avoid driving uphill on over 2% grade except as made necessary to fulfill condition (*c*); and (*g*) to have all headings either level or sloping toward the drainage shaft.

At the upstream end of the siphon is a so-called downtake chamber connecting the aqueduct at the hydraulic gradient with the so-called downtake shaft. This chamber contains stop-plank grooves for shutting off the residual flow of the aqueduct from the tunnel after the aqueduct has been put out of service and is nearly drained; screen racks to prevent large objects from going into the shaft; a crane and other facilities for handling cover plates and beams, etc., over the shaft; and withal is a safeguard for the top of the shaft. Plate 40 shows a similar downtake chamber designed for Moodna siphon. The Rondout chamber, of which no drawing is shown, is complicated by having a connection for the future Rondout Aqueduct and an overflow weir large enough to take the full flow of the Rondout Aqueduct.

At the downstream end of the siphon is the so-called uptake chamber, connecting the aqueduct at the hydraulic gradient with the so-called uptake shaft. This chamber performs similar functions to the downtake chamber and has stop-planks and a crane, but in place of the screen racks has a two-rail barrier to prevent maintenance workmen from inadvertently falling into the shaft.

As this tunnel is nearly 5 miles long, 6 shafts were necessary in addition to the downtake and uptake shafts to enable construction to be completed in the 4½ years reckoned as available. One of these intermediate shafts is to be finished for a drainage shaft to enable the tunnel to be pumped out for maintenance purposes. Of this, more will be said later. The other five shafts are to be plugged with 50 or 75 ft. of solid concrete grouted next to the rock and then partly or wholly filled in with tunnel muck.

Wallkill Siphon.—The Wallkill siphon is substantially equal in length and like the Rondout siphon in arrangement. Being entirely in soft rock, Hudson River shale, and in rock which comes closer to the surface of the ground so as to permit the tunnel to be

higher and shafts less deep, this tunnel required but 6 shafts in all as against the 8 in Rondout siphon.

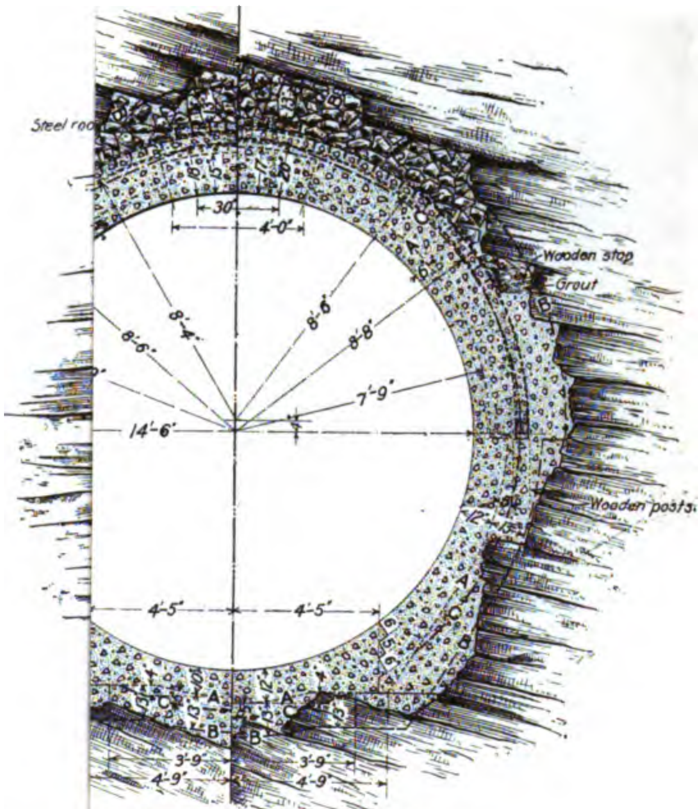
Moodna and Hudson River Siphons.—Plate 33 shows the Moodna siphon and the Hudson River siphon as contemplated, provided Mother Earth will supply sound rock at a depth not much exceeding half a mile. The Moodna and the Hudson siphon are substantially one siphon, the downtake shaft and chamber being at the northerly end of the Moodna, the uptake shaft and chamber being at the easterly end of the Hudson River siphon and the drainage shaft for both being at the easterly shore of the Hudson River near the uptake shaft. Near the west shore of the Hudson River is a construction shaft on the Moodna siphon which it is contemplated to line as an access shaft. From this same shaft, if necessary, can be run one or more temporary submerged steel pipe lines connecting the Moodna siphon with the aqueduct east of the Hudson if the construction period of the permanent crossing is too much prolonged by the depth to rock in the Hudson River.

Foundry Brook, Sprout Brook and Peekskill Siphons.—Next in geographical order come three siphons which were each explored rather thoroughly by borings with the hope that they would be pressure tunnels, but in each of which geological conditions were found which caused steel pipe to be adopted. Foundry Brook siphon crosses a gneiss valley, but the rock was found much decomposed in places, the geologists' theory being that deep decomposition had occurred and the disintegrated rock still lay on the firmer rock due to the north side of the valley being in the lee of the high Breakneck range and so protected from glaciation. The rock dips steeply and occasional layers seemed disintegrated to an indefinite depth due probably to faulting.

Conditions at Sprout Brook were generally unfavorable for a shallow tunnel and the narrowness of the valley made a pressure tunnel uneconomical as already explained.

Peekskill siphon would apparently have been cheaper as a pressure tunnel than as a steel pipe but for the presence of a thick, nearly vertical bed of limestone which the borings indicated to be decomposed in places almost to the consistency of granulated sugar. Since the only way to disprove the danger was by expensive further exploration by shafts or by very large shot drill borings, such as are used for elevators, the pressure tunnel project was abandoned.

PLATE 36.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



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City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
STANDARD TYPES OF PRESSURE TUNNELS

FEBRUARY 15, 1908.

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Croton Lake Siphon.—The next pressure tunnel in order is the Croton Lake siphon. This differs from the Rondout and Wallkill siphons in being so short (about 2 640 ft.) as to require only the permanent end shafts, *i. e.*, the downtake and uptake shafts, to enable it to be completed in the 43 months thought to be available for its construction. The absence of an intermediate shaft makes it necessary to use one of the end shafts, in this case the downtake shaft, for a drainage shaft. The downtake chamber is an unusually complicated structure, combining the functions of (*a*) a regular downtake chamber; (*b*) a drainage chamber; (*c*) a connection chamber for a possible high level aqueduct for the purpose of taking some of the water of the Croton shed into the higher Catskill Aqueduct; (*d*) an overflow weir chamber, the weir being for the double purpose of preventing head on the aqueduct in case Kensico Reservoir receives a flood from its own shed at the same time the Catskill Aqueduct is discharging more than it can when flowing full, and to take excess flow up to the full capacity of the high-level Croton Aqueduct, in case the latter is built, and both aqueducts should by gross error be turned on at full capacity; and (*e*) a chamber for a full capacity blow-off capable of intercepting the full flow of the aqueduct in case a break occurs south. This blow-off will be explained later on.

Yonkers Siphon.—Plate 33 and, more in detail, Plate 34 show the proposed Yonkers siphon (11 800 ft. long) which is really a continuation of the Bryn Mawr steel pipe siphon (6 000 ft. long) and was adopted partly because considerable embankment or reinforcement would be needed for an aqueduct in open cut at or near the hydraulic gradient, and partly because real estate is so dear and other local conditions are such as to make the pressure tunnel, which can be placed largely under public highways, more economical than the aqueduct at the hydraulic gradient. This pressure tunnel is the only one that is above the surrounding valleys and in which the minimum rock cover is less than 150 ft. Its elevation enables it to be drained by gravity and the maximum unbalanced head is small, like that in the existing pressure tunnels described.

City Siphons.—To terminate the Catskill Aqueduct at Hill View Reservoir, would be to leave many miles of aqueduct of some kind to be supplied for bringing the water to where it can be used, viz., to the distributing systems of all the boroughs. To supply this

connection the Catskill aqueduct is to be extended as a pressure tunnel running practically the whole length of Manhattan, crossing under the East River at about Clinton Street, Manhattan, and Bridge Street, Brooklyn, and extending about a mile into Brooklyn. Connections are proposed to the distribution system at each of the approximately 24 shafts; and extension into Brooklyn, Queens, and Richmond are proposed of steel pipe. A drainage shaft is contemplated at or near the Harlem River and another at the East River. Others may be found advisable. Two or three valves in this extension tunnel are proposed.

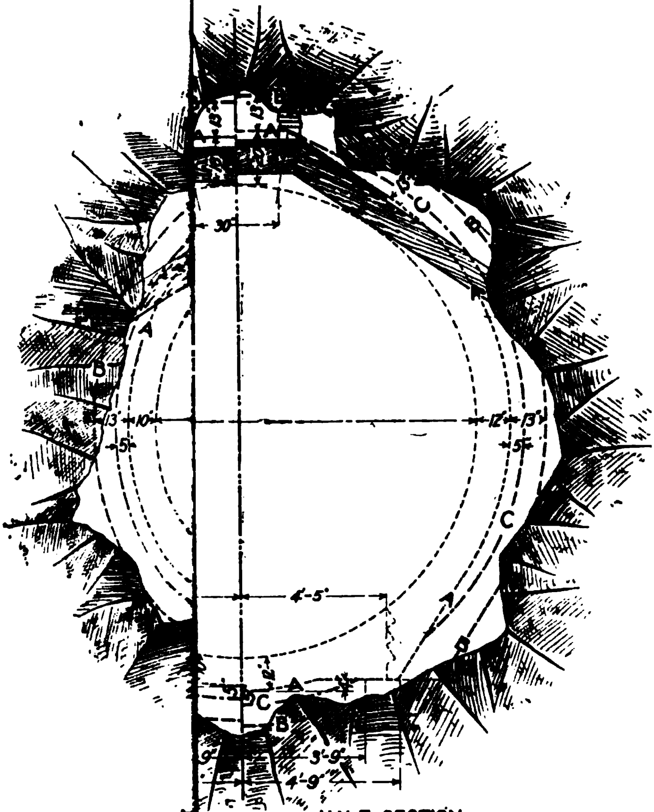
This tunnel system promises much economy over a system composed of metal pipes, because the New York streets are so full of pipes, conduits and subways that distribution pipes could not be over about 5 ft. in diameter and it would take about 18 such pipe lines to carry as much as the one proposed tunnel. The ability to make one tunnel as against 4 metal pipes you will recall was responsible for the comparative economy of the pressure tunnel in the Catskill Aqueduct above Hill View Reservoir. It will be readily inferred how much greater the comparative economy of the single tunnel is when compared with the 12 or more pipe lines which would have the same capacity.

Design of Pressure Tunnels.

Returning now to the details of design of the pressure tunnels:

Depth.—The writer has from the start strongly advocated placing the tunnels under a heavy cover of sound rock. He suggested 150 ft. as the minimum cover of sound rock in the case of Wallkill siphon, which was the first pressure tunnel to be considered in detail. This was accepted by the Chief Engineer and has been used for the Rondout, Wallkill, Moodna and Croton Lake siphons, though not without suggestion on the part of prominent engineers in the Board's force, that money could be safely saved by decreasing this minimum rock cover. Thus it was proposed to place the Moodna siphon tunnel arch within about 25 ft. of the surface of rock for certain short stretches in order to permit draining by gravity into the Hudson River. The more conservative course was chosen, however, here as in all other cases, since it is solemnly realized that the large unbalanced heads in pressure tun-

PLATE 37.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



HALF SECTION

14-6" DIAMETER

City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
STANDARD TYPES OF PRESSURE TUNNELS

FEBRUARY 15, 1906

Drawn by R.H.J. Traced by J.S.V. Checked by W.J. T. Thos. H. Wiggin ... ng Hdqrs

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nels of the Catskill Aqueduct have no counterpart in tunnels now in operation.

At either shore of the Hudson River, where the upper tunnels join the deep shafts, the depth of these upper tunnels was determined such that the weight of each vertical prism of rock extending from the tunnel to the rock surface is equal to the pressure which would result from a column of water extending to the hydraulic gradient acting at the base of the prism, or in perhaps plainer words, on the assumption that the dead weight of the rock should exceed the upward pressure even if the latter spread out indefinitely undiminished. This allows nothing for effect of interlocking of the pieces into which the ledge is presumably divided by cracks. The assumption resulted in fixing the upper tunnels at a depth of about 200 ft. below the surface or at an elevation of about — 185.

In studying each of the siphons a line has been drawn on the profile representing the depth at which the water column, reckoned to the hydraulic gradient, is thus balanced by the dead weight of rock and earth. The 150-ft. limit already mentioned has resulted in greater depths usually and has controlled in all cases except that of the Hudson River shore headings mentioned above; the Rondout siphon, which went deeper still for reasons mentioned on page 109; and the Yonkers siphon which has only light heads and is treated specially as has been described. It will be recalled that the Cincinnati land tunnel was reinforced for 1 000 ft. where the dead weight of the cover was insufficient (see p. 107).

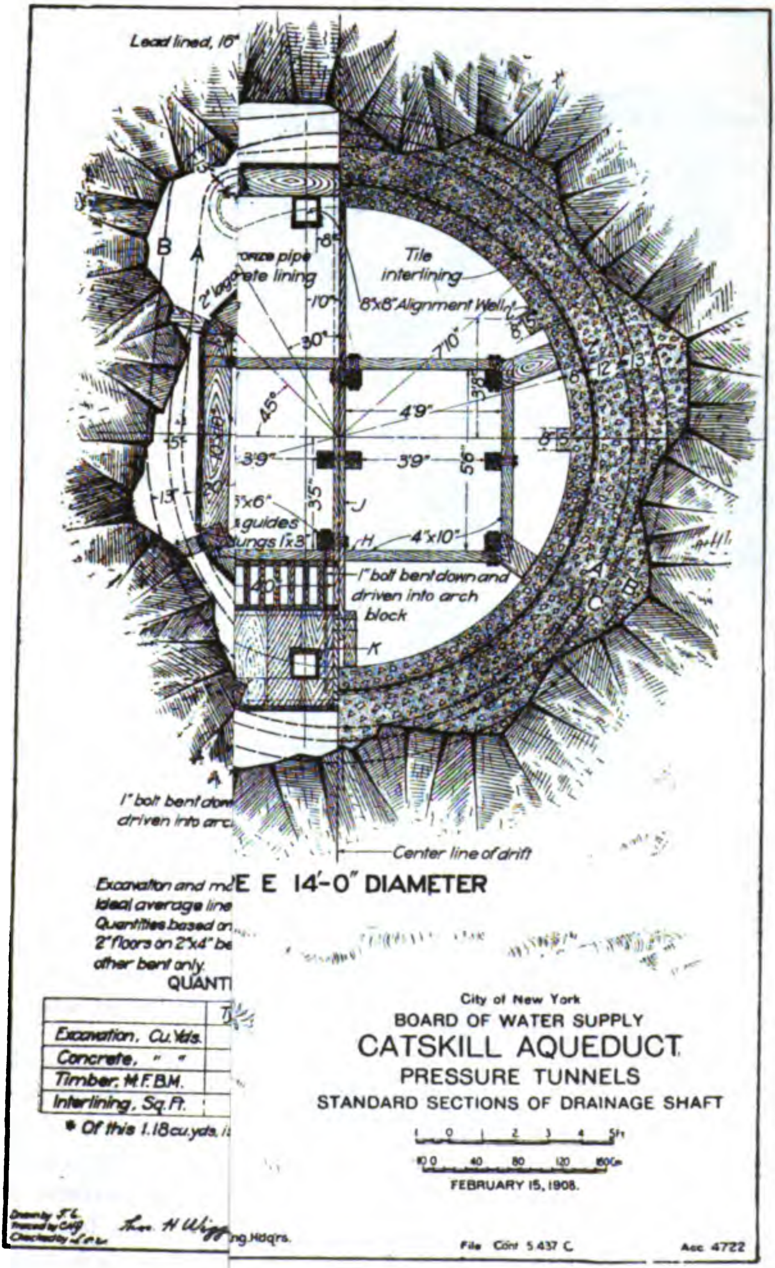
Shape of Tunnel and Shaft Sections and Thickness of Lining.— Plates 35 to 38 show typical sections of pressure tunnel and permanent shafts as given in contract drawings. The circular shape was adopted at the outset for pressure tunnels and permanent shafts because of the external pressure which they may in places be called on to carry when the tunnel is under construction or out of service. The writer has always recognized that the external pressure from ground water depends on the relative porosity of the rock and concrete. Thus, with a tight lining and porous rock the lining would receive nearly the full ground-water head; with a tight rock and an equally impervious lining the lining would get little pressure, since the pressure would be mostly lost in the much thicker rock; also with a tight rock and porous lining the lining would receive

practically no pressure. It is hoped by the writer that any porous or seamy rock may be so made tight by grouting as to constitute the main reliance against inward or outward leakage. The process specified will be described later.

The writer expects that when this grouting is done the ground-water head must be overcome in many places (experience elsewhere has borne this out) though a part of the tunnels will require less pressure, due to relief into ungrouted portions notwithstanding cut-off walls are specified to prevent such relief and enable the grouting to be completed in stretches about 50 ft. long. The writer does not believe that such severe conditions on the lining will occur after grouting. The grout is applied at full pressure and in generous quantities directly between rock and lining. It is furthermore of a nature to stop the leaks in the concrete which would otherwise tend to relieve the pressure. For all these reasons the writer recommended that the tunnels and permanent shafts be designed circular and that linings be made of such thickness as to endure the whole ground-water head but with a low factor of safety, since (*a*) the conditions of maximum stress would not be duplicated after grouting; (*b*) the periods of unbalanced external pressure would be short and infrequent, viz., when the tunnel was out of service and pumped out; and (*c*) any failure during grouting would be evident and could be remedied. 1 500 lb. per sq. in. was adopted by the writer as a permissible maximum compressive stress for the 1:2:4 concrete lining.

In computing the thickness of lining for a maximum stress of 1 500 lb. per sq. in., the thick hollow cylinder formula of Lamé was used. The outside of the lining of a rock tunnel is of course very rough, and a circle has to be assumed in computing. This (called the "C line") is taken as 5 in. outside of the line ("A line") within which no rock is permitted to project, and the specification provides that the lining shall everywhere actually average to this 5-in. line, the rock being trimmed back of the "A line" if necessary. At the same time the contractor is paid for a thickness averaging to the "B line," which is 13 in. outside the "A line," or line within which no rock may project, this 13 in. having been determined from many tunnels as a good average figure. Thus a tunnel or shaft lining having a minimum thickness (*i. e.*, thickness to "A line") of

PLATE 38.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



10 in. will be computed as having everywhere an effective thickness (*i. e.*, to "C line") of 15 in. and will be paid for as having an average thickness of 23 in. (*i. e.*, "B line"). Appendix 4 gives an arrangement of Lamé's formula, by Mr. Russell Suter, of the writer's force, for convenient use in computing necessary thicknesses of lining for any diameter of tunnel or pressure. A diagram is used in practice. The table (p. 116) gives data, assumptions, and computed thicknesses for pressure tunnels of the Catskill aqueduct; also at the end certain computations illustrating the enormous effect on computed thicknesses of changes in maximum allowable compressive stress assumed.

In deciding on the thicknesses given in column 7 account was taken of the following considerations:

1. No thickness less than 5 in. to the "A line" (= 10 in. to "C line") is permissible because the projecting points of rock would be in the way of erecting panels of form lagging. This minimum was recommended by Consulting Engineer F. P. Stearns after experience with 4 in.
2. Not generally necessary to provide for heads up to the top of the end shafts, which are on side hill locations, because drainage into the end shafts will draw down the ground-water head and keep it down until after tunnel grouting is done (provided, as was assumed, the rock shaft is grouted last). Less pronounced slopes of ground-water head were in any case expected at tunnel grade. The general average of the valley to the foot of the hill was taken in computing thickness.
3. General advisability of substantial linings for the larger tunnels somewhat irrespective of stresses. This influenced also by thought of waterproofness.

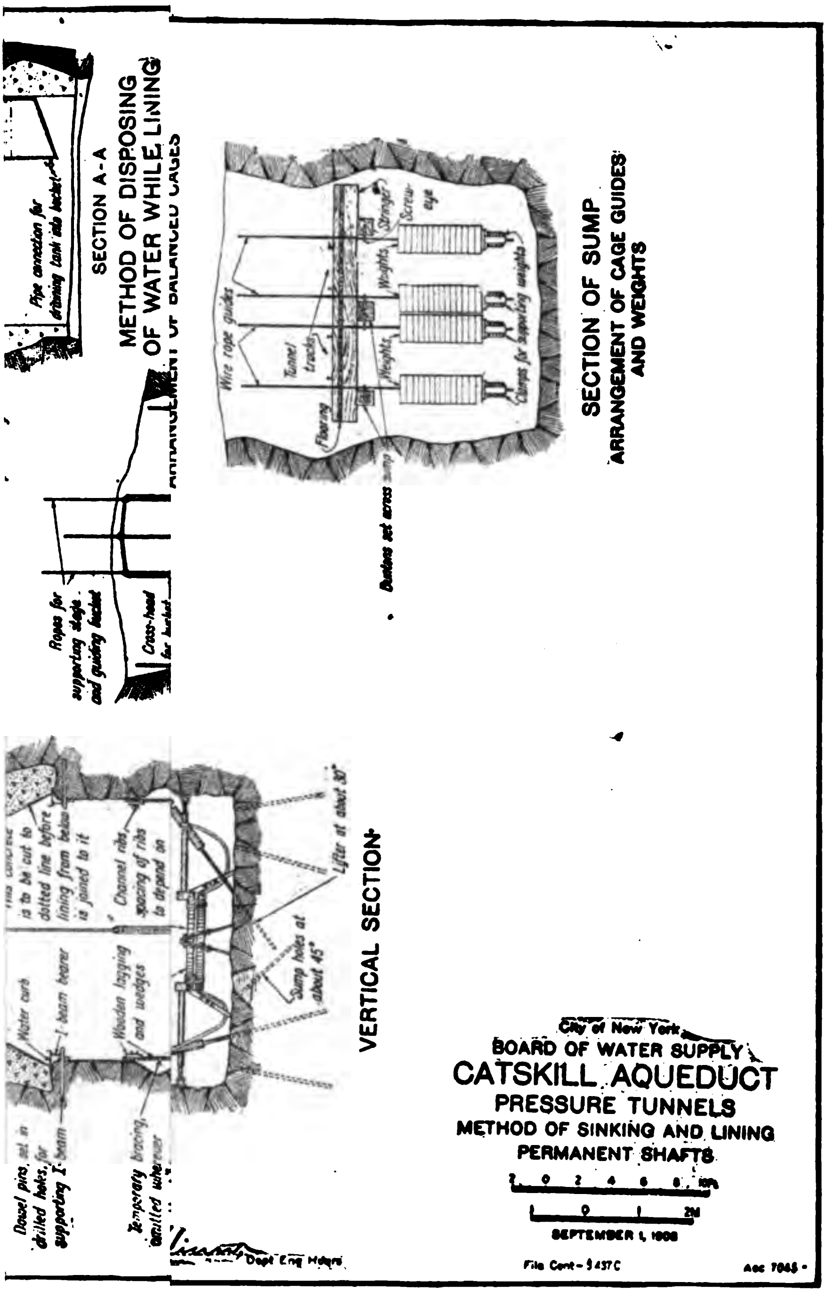
This attempt to put the "judgment" of experienced engineers into words is always unsuccessful and the above attempt is no exception. The Chief Engineer and the Consulting Engineer, who together looked over the first computed thicknesses, were apparently more impressed with the reasonableness of the results than of the method and units, and the writer is not sure that he would have thought of so many reasons why a low factor of safety was ad-

CATSKILL AQUEDUCT PRESSURE TUNNELS,

Computed and Chosen Thicknesses of Lining; also Miscellaneous Illustrative Figures.

1	2	3	4			5	6	7	8
Name of Siphon.	Internal Diameter, Feet.	Assumed Maximum Compressive Stress, Lbs. per Sq. In.	Depths below surface, *i. e.*, external Head of Water, Feet.			Computed Thickness of Lining (to "C Line"), Thick Cylinder Formula.	Thickness by Ordinary Thin Cylinder Formula.	Chosen* Thickness of Lining (to "C Line"), Inches.	General Maximum Depths† below surface—*i. e.*, exceeded only for short isolated stretches or at end shafts on hillsides. Also Remarks.
			Max.	Min.	For Col. 7.				
Rondout.............	14' 6"	1 500	710	345	519	2.26' = 27" 0.86' = 10"	1.32' = 16"	17	460' and 530'
Wallkill..............	14' 6"	1 500	483	265	475	1.27' = 15" 0.62' = 7.5"	1.18' = 14"	15	360'
Moodna..............	14' 2"	1 500	670	270	485	2.06' = 25" 0.61' = 7.5"	1.17' = 14"	15	500'
Croton Lake........	14' 0"	1 500	550	345	430	1.48' = 18" 0.83' = 10"	1.00' = 12"	13	350'
Yonkers.............	16' 7"	1 500	180	100	425	0.47' = 6" 0.25' = 3"	1.14' = 14"	15	170'
Van Cortland........	15' 0"	1 500	275	210	410	0.67' = 8" 0.49' = 5"	1.02' = 12"	13	250'

PLATE 39.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



Bronx...............	15' 0"	1 500	440	185		1.18' = 14" 0.43' = 5"			
					410 460		1.02' = 12" 1.16' = 14"	18 15	280' and 420'
Central Park........	15' 0"	1 500	400	375		1.05' = 12.5" 0.98' = 12"			
					460		1.16' = 14"	15	390'
	14' 0'	1 500	460	170		1.17' = 14" 0.36' = 4"			
					490 445		1.17' = 14" 1.08' = 12"	15 18	490' and 240'
Sixth Ave.	14' 0"	1 500	190	190	445	0.43' = 5"	1.08' = 12"	18	190'
	13' 0"	1 500	200	180		0.41' = 5" 0.37' = 4.5"			
					460		1.01' = 12"	18	190'
	12' 0"	1 500	205	205	425	0.39' = 4.5"	0.87' = 10.5"	11	205'
East River..........	12' 0"	1 500	640	200		1.58' = 19" 0.37' = 4.5"			
					425 to 645		0.87' = 10.5" 1.42' = 17"	11 to 19	Practically all (6 500') is on incline 200' to 640' depth.
	11 0'	640	300			1.42' = 17" 0.52' = 6"			
					635 [illegible]		1.27' = 15" 0.90' = 11"	17 11	640' and 350'
Hudson River illustrative figures.....	14' 0" 14' 0' 14' 0" 14 0"	1 500 1 500 1 500 2 500	....	....	1 850 1 500 1 780 1 500	7.9' = 95" 12.3' = 148" ∝ 3.18' = 38"	4.5' = 54" 5.4' = 65" 7.0' = 84" 2.46' = 30"	....	Shows what rich concrete could do.
Miscel. illustrative figures............	14' 0" 14' 0" 14' 0" 14' 0"	565 600 900 1 500	....	....	650 650 650 650	∝ 21.5 4.3 1.83	7.0 6.2 3.2 1.6	....	Note rapid decrease of thickness as allowable stress is increased.

* For general use for City siphons, *i. e.*, Van Cortland, Bronx, etc., depths are as recommended, but are not yet approved. † Two depths are given under a siphon and diameter in cases where tunnel is on two general levels – in these cases levels are connected by 9% to 15% inclines. General depths are placed after chosen thicknesses for the same stretches.

missible, if its desirability had not first been demonstrated by the great thickness (infinite for a stress of 565 lb. at a head of 650 ft.) resulting from ordinary working stresses. The last 4 lines of the table show these initial stimulating computations.

The Hudson River siphon is the only one so deep as to make absurd the practical application of the 1 500 lb. unit stress. Elsewhere the thicknesses thus determined are generally less than those decided on "for looks." For the Hudson River siphon, the writer would use thicker or stronger* lining only where porous rock exists, which, it is hoped, will be infrequent.

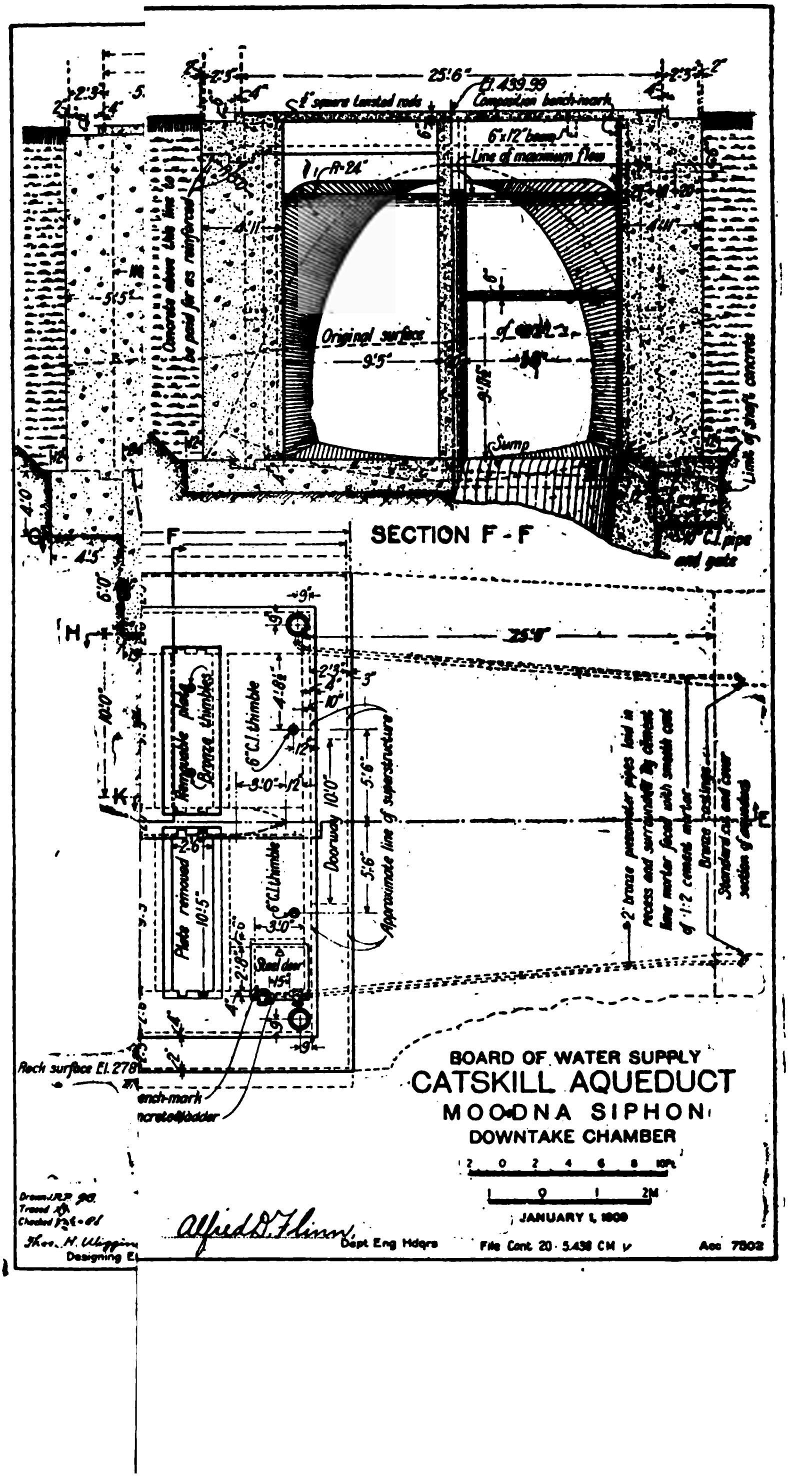
Mr. John R. Freeman suggests that no concrete could be made tight enough to exclude the water so completely as to permit anything like full pressure of such intensity to come on the lining. A quick canvass of conveniently available porosity tests made in the Board of Water Supply laboratory showed an average leakage of 43 grams in 10 minutes at 40 lb. pressure and 122 grams at 80 lb. Specimens were of 1:7, 1:8, 1:9 and 1:10 concrete of various kinds and were 8 in. diameter and 6 in. thick. The mortar skin had been picked off. Assuming the pressure-leakage curve to be a straight line† passing through the origin, drawing the line through 106 grams at 80 lb. (that is, on the assumption that the errors are in observation), and extrapolating to 585 lb. pressure (depth 1 350 ft.), also assuming leakage in a tunnel lining 17 in. thick to be $\frac{6}{17}$, as much per unit of area as in a 6-in. specimen,† gives an inward leakage of about one gallon per minute per foot of 14-ft. tunnel, *if* the water surrounded the lining at all points. The porosity of such concrete would relieve the pressure greatly if ordinary leakage were uniformly distributed over the back of the lining. Since, however, the initial leakage through the rock is likely to be concentrated at occasional crevices, it seems that before grouting there might be full pressure in the lining at such crevices. At such places, as above noted, the writer would strengthen the lining.

It should be remembered that a relatively high rate of leakage

* For very large heads and, indeed, elsewhere, the writer would think seriously of increasing the richness of the concrete so as to permit a higher stress and give greater imperviousness. This enriching of the concrete is an almost universally overlooked expedient for increasing both strength and imperviousness. It may play an important rôle in difficult and important parts of the pressure tunnel construction. Thus it would cost only about \$2 per yard of concrete, or about \$8 per foot of 14 ft. tunnel with lining 16 in. to "C line" (24 in. average thickness), to make concrete having 1 cement to 8 aggregates instead of 1 cement to 6 aggregates, and both strength and imperviousness would be about doubled.

† Assumptions open to question, but consistent.

PLATE 40.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



through a few points in the rock along the tunnel will not mean large total leakage in the completed tunnel, since the lining, while not tight enough to serve as the only water stop for the whole area of the tunnel, *is* tight enough to make a very respectable stop over the small percentage of the rock surface which will require such assistance if the grouting is not always effective in filling the crevices well back from the tunnel. As before stated, the writer prefers to think of the lining as a smooth coating to produce a high coefficient of flow and a bulkhead serving temporarily to retain the grout and enable it to be forced into the voids in the rock, the rock being thereafter the main water stop.

The writer has always realized, as has been ingeniously worked out quantitatively by one of his assistants, Mr. R. H. Stearns, that special stresses (which according to the computations are of a startling magnitude) were likely to be computable where the pressure is applied to only a part of the exterior, which is generally true, since the space over the arch is generally the only part which will take the grout. To increase the factor of safety would be expensive, and somehow these extremely complete determinations of stress seem frequently to condemn that which has often been successfully used. If there seems likelihood, at any place, of pressures, other than grouting pressures, of such magnitude on the lining, then for such places the writer would strengthen the lining locally, as found needed. The writer would wait for a failure before building safer, as the extreme condition would not, he believes, be again approached after construction.

Tunnel Sections in Detail.

Types A and B, Plate 35.—Types A and B are for rock not requiring support. Type A is for use where lining is to be done in a heading after excavation has been completed, so that a section of lining can be built monolithic or at least invert first. Type B is for use when traffic must be maintained while the side-walls and arch are being lined: note the enlarged excavation for footing of side-walls. At the crown the sections are alike. Note that the "C line" or line of effective thickness, is raised so as to make the crown thickness 3 in. greater than the thickness elsewhere to the "C line" and that the "A line" is also raised to eliminate points of rock which, while permitted 5 in. inside the "C line" elsewhere,

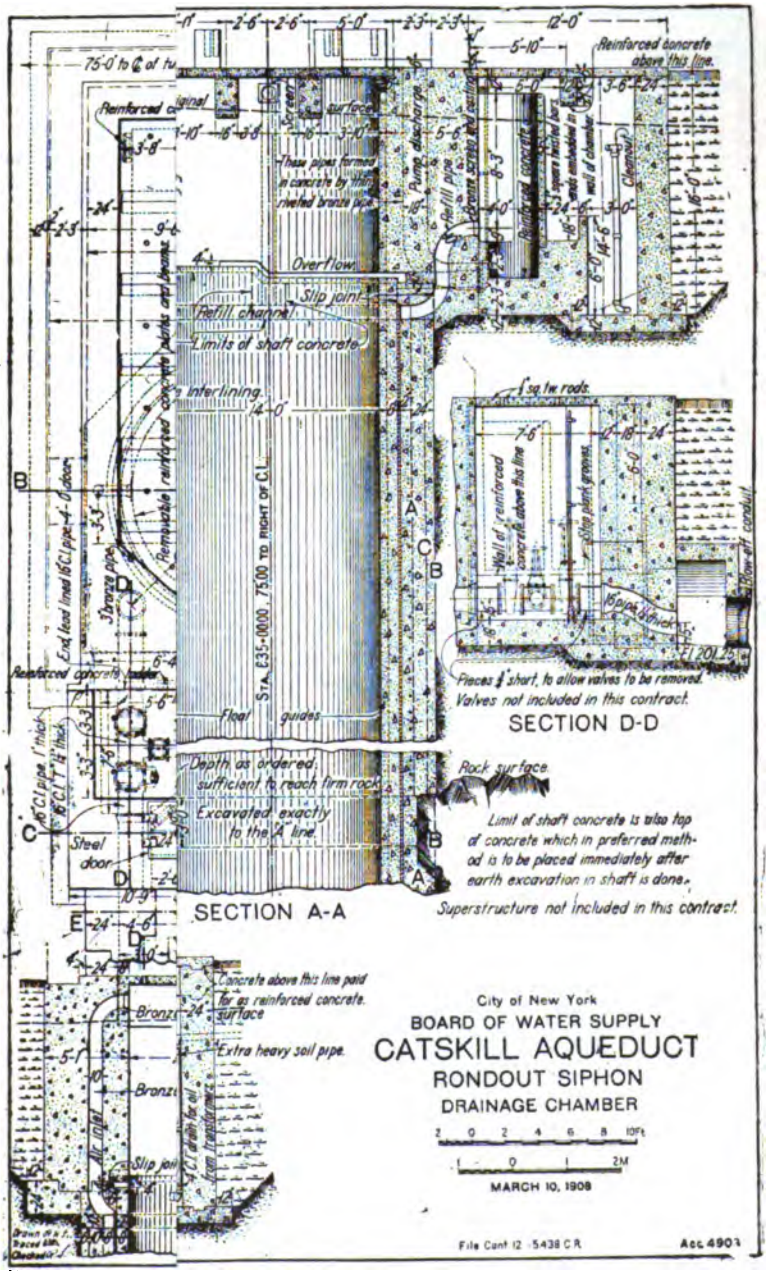
would hinder placing the arch key. The extra thickness is provided in recognition of the difficulty of getting as good concrete in the key as elsewhere.

Types C and D, Plate 36.—Types C and D correspond to Types A and B respectively as regards invert. They are like each other elsewhere, being for ground requiring permanent support. For this permanent support it is planned to use steel ribs consisting of curved 5-in. or 6-in. I-beams and steel lagging, consisting of 3 in. by 3 in. by ¼ in. angles, spaced as may be seen in Plate 36. Wooden posts are permitted for supporting the wall plates and through them the whole system of support. The reason for the steel lagging will be evident when one thinks that a sheet of wooden lagging, soaked with water and in bearing across grain, also weakened no one can predict how much by age, would be a poor substance to transmit to the rock the internal pressure of 100 to 500 lb. or more per square inch. Wooden ribs might be used, since the stress could be carried around them, but Mr. L. P. Wood suggested and demonstrated by estimates that it was slightly more economical to use steel for the ribs also, since excavation and concrete is saved. Steel support is becoming increasingly common in coal mines.

Between the tunnel sections is shown a panel lagged with wood. This panel was designed for use every 50 ft. or so in permanently supported tunnel. The lagging is to be taken down when the concrete gets up near it, and a grouting cut-off wall built tightly against the rock roof.

Types E and F, Plate 37.—Types E and F are like A and B with respect to shape of excavation and permanent lining. The only difference is in the use of bents of light partial timbering designed to temporarily support slightly scaling rock and to be removed when the section is concreted. This type originated in the Department of our past-president, Mr. Robert Ridgway, and the writer has never quite assimilated it though it is being extensively used in Mr. Ridgway's work. The delay attendant upon taking it down during concreting, makes it seem like a doubtful economy to the writer, and all concrete placers, especially those placing the key, will be exposed to a little more danger than would be the case otherwise.

PLATE 41.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



Designs for Shafts.

The permanent shafts are circular for reasons already given. This type of shaft was at first thought by most of the field engineers and by the contractors to be slower and more expensive than the rectangular shaft with which they were all familiar, and experience on the first job, where both types of shaft were being sunk, confirmed the impression, though the difference was not great. The circular shaft has been almost universal in Europe, and, after the methods there used were learned by the contractors, the circular shaft became popular, and I believe it now holds all the records on the Board of Water Supply work for speed and economy. It should be said that all these records are for shafts in shale.

Circular Shafts in Rock.—The permanent shafts in rock are comparatively simple since it is not dangerous to remove the support as the concreting progresses. The support is all temporary, but more or less so according to procedure. The first design of support, mainly the idea of Mr. L. P. Wood and used for the Rondout siphons, consists of octagonal sets of wooden arch blocks with lagging. Supported from the sets is a system of vertical posts strong enough to stand as a trestle clear from the bottom of the shaft so as to remain for the support of guides and pipes after the shaft has been concreted, thus permitting practically uninterrupted service into the tunnel for grouting or other purposes. It is contemplated to brace the post system from the lining as the lining progresses and requires supports to be removed. Plate 38 shows the timbering and posts. The shaft shown is a drainage shaft with double lining, but the principle is the same for water-way shafts. In the drainage shaft a second transfer of bracing is necessary, *i. e.*, to the inner lining as it progresses, the outer lining having been first completed and the post system braced to it.

The post system is expensive of timber and time, and after study of the European methods were advanced far enough shaft support was omitted from drawings of permanent shafts, except as indicated on Plate 39 for temporary use. This drawing, made under the immediate direction of Mr. Russell Suter, shows a composite of the most approved European methods. The specifications for all pressure tunnel contracts, except for the Rondout siphon, require that the method indicated on this plate be used unless the Engineer

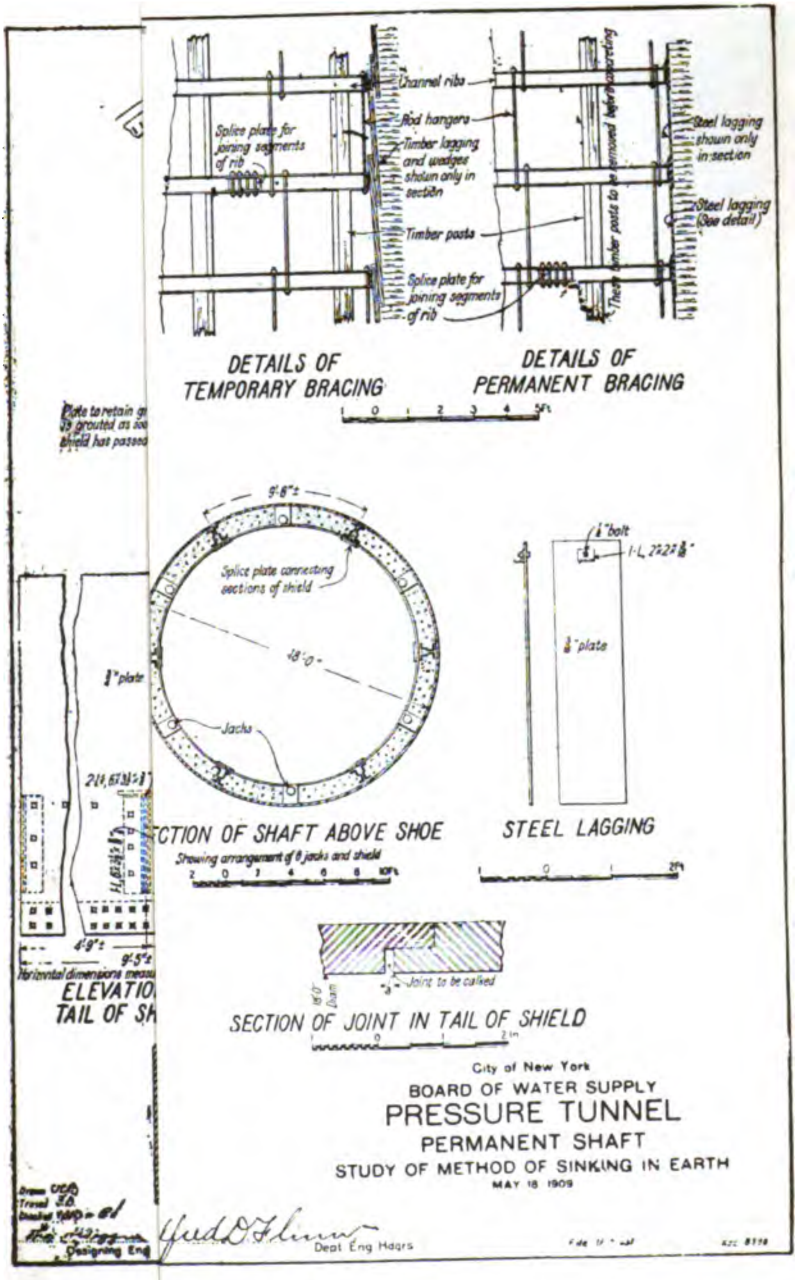
shall be convinced that the contractor has a better one. The method consists essentially of sinking continuously and lining upward in stretches of 50 ft. or so, beginning within 10 to 25 ft. of the bottom of excavation according as the rock is soft or hard. Lining may be done way to the bottom, if necessary to stop large inflows of water. Special care is then necessary in continuing excavation to avoid injury to the concrete. Wire ropes with weights to anchor them are used for guides and the muck buckets pass through a platform from which lining is done. The support where needed is lagging or poling boards, braced by circular ribs. It may be used over and over, as it is promptly removed. It is estimated that the cost of support saved over the old method is sufficient to pay for the concrete lining. The method is now being used in part in Wallkill, Moodna and Croton Lake siphons.

Curve at Foot of Water-way Shaft.—In order to save head, the concrete lining at the foot of water-way shafts is made in the form of a reasonably good quarter-bend. The form is expensive but the saving in head (worth at least $50 000 per foot in saving size of aqueduct) will pay for the form several times over. Two bronze anchor bolts are provided for future attachment, during maintenance, of wire rope cage-guides. Perfection of shape in the curve as a water-way is sacrificed, and also a flat recess in the curve is formed at the bottom, in the center of the shaft, to permit maintenance cages to be lowered close to the bottom of the tunnel instead of being stopped by the curved surface.

If desired to lessen friction losses, the recess may be filled with weak, easily-removable concrete plastered smooth with strong mortar.

Permanent Shafts in Earth.—Equal in difficulty to any work known on these siphons, is the sinking and lining of circular earth shafts. This is because a heavy siphon or pumping chamber and superstructure are to be built at the head of each such shaft and settlement would make such buildings eyesores, even if dangerous leaks were not developed. Every effort was made to find for these permanent shafts locations where rock came near enough to the surface to permit the chambers to rest on the rock. In 6 out of 15 chambers over shafts of pressure tunnels between Ashokan and Hill View reservoirs, rock could not be found high enough, being

PLATE 42.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



for the six cases respectively 67, 38, 36, 35, 139, and 26 ft. below the chamber bottom. For these cases the designs and specifications were prepared on the basis of so excavating, lining and grouting the earth shafts as to forever prevent any settlement of the earth around the shaft. Plate 40 shows the design for the downtake shaft of Moodna siphon, and Plate 41 the design for the drainage chamber of Rondout siphon. In the latter the division lines between shaft lining and chamber bottom are such as to form a slip joint which would permit slight settlement. Such design is less objectionable in the drainage chamber, which seldom contains much water, than in the downtake and uptake chambers, which are part of the aqueduct waterway. Various designs for slip joints for these latter chambers are available and other remedies are in mind, in case some one blunders and fails to prevent movement of the ground. As an extreme precaution, permanent shafts in earth are reinforced against internal pressure, just as strongly as if the ground were not in contact with them. The writer provided this, conceiving the possibility, at some point unknown and hence everywhere to be guarded against, of the ground being either not in contact with the lining for a distance sufficient to permit fracture of the lining, or so slightly in contact as to be compressed sufficiently to permit fracture. The radial distortion of the lining at fracture would be only about $\frac{1}{80}$ in. and the writer knows of no measurement of the compression of earth necessary to develop its passive resistance to the extent of 1 to 3 tons per square foot.

The following quotation from a typical set of specifications for permanent shafts in earth, will give the best conception of the kind of work expected:

"DOWNTAKE SHAFT IN EARTH.

ITEM 7.

SECT. 7.1. Under Item 7 the Contractor shall sink the earth portion of the downtake shaft, Shaft 1. Special precautions shall be taken, as hereinafter described, to prevent any ultimate settlement of the ground around the shaft which would cause dangerous leaks in the heavy chamber to be placed on this ground and unsightly cracks in the superstructure..

....

SECT. 7.2. Before commencing work the Contractor shall file with the Engineer, and receive the Engineer's written acceptance of, a description of the methods which he proposes to employ..

....

SECT. 7.3. Support for the ground shall be sufficiently strong and rigid to prevent beyond question any movement of the ground due to distortion of the support. Unless

otherwise permitted a type of support shall be used which is built downward as excavation progresses, so so as to eliminate continued disturbance of the ground adjacent to excavated portions of shaft and permit grouting behind support in upper portions before the whole shaft is completed. Segments of cast or fabricated metal joined by flanges and braced, and for the top or extreme bottom, relatively short lengths of steel piling will fulfill these conditions. Strong and well-braced ribs with wooden, metal or reinforced concrete lagging may be permitted if joints are devised which will permit grouting behind such types of support or if the ground is so firm as to make grouting behind the support unnecessary.

SECT. 7.4. Provisions shall be made for placing masonry lining in the excavated portion of the shaft and beginning the use of a shield method of sinking at any point in the depth, if running ground is encountered which cannot be otherwise handled, and air shall be used if necessary to prevent running in which would cause serious subsequent settlement. A caisson or drop shaft sunk from the surface shall be used only in case running ground is actually encountered near the surface. A return to the method described in Section 7.3 shall be made as soon as either shield or caisson, as the case may be, has passed the running ground. In any stretch ordered, measurement shall be made under Engineer's direction of the quantity of material being excavated, and tests made to determine the changes in volume due to excavating, so that a check on the precautions against settlement may be made.

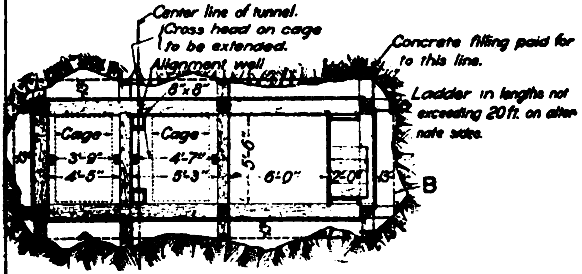
SECT. 7.5. Excavation shall be made as accurately as possible to the form and position of the outside of the support. All voids outside this support exceeding one-eighth cubic foot in volume, due to the removal of boulders or other causes, shall be tightly packed with clay before covering them with the support.

SECT. 7.6. As soon as practicable after any section of support is in place, unless otherwise permitted as provided in Section 7.3, all voids outside such support shall be completely filled with grout of required proportions, not richer than one volume of cement to one volume of fine sand. Connections for 1-inch standard steel pipe shall be provided through the support where necessary for this purpose, but not farther than 8 feet apart, vertically and horizontally.

SECT. 7.7. As a part of the work under this item the Contractor shall excavate the shaft through whatever loose or unsound rock there may be at the top of the bed-rock, so as to afford a firm foundation and water-tight junction for the concrete lining, which is to be immediately placed as specfied in Section 20.12."

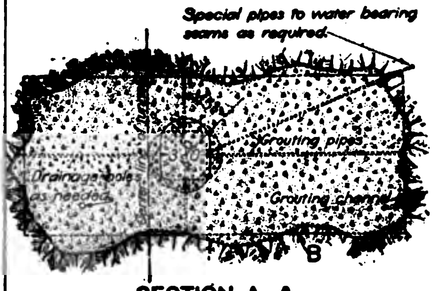
Plate 42 is the study of method for such shafts that was made, before the above specifications were written, to illustrate the various contingencies thought possible. Like Plate 39 illustrating rock shaft methods, it is simply an adaptation to our conditions of methods that have been successful elsewhere. With what proved to be excessive caution, concrete drop shafts were used for the two permanent air shafts of the Rondout siphon. One shaft was in very firm hardpan, and after great difficulties in sinking the caisson part way, it was left suspended and the earth shaft completed by timbering methods. The other was in less hard but firm clay, and the caisson hung at its top and broke apart, requiring troublesome repairs. The caisson leaves voids between it and the earth, which cannot be grouted until the caisson comes to rest at the completion of the shaft in earth. Time is hence available for movement of the ground, and consequent settlement. This, combined with the impossibility of keeping it exactly plumb, makes it objectionable for the permanent shafts of the Catskill Aqueduct. Permanent earth

PLATE 43.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



PLAN OF SHAFT TIMBERING

2 0 2 4 6 8 10Ft.
1 0 1 2M



SECTION A-A

2 0 2 4 6 8 10Ft.
1 0 1 2M

City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
PRESSURE TUNNELS
CONSTRUCTION SHAFT

10 2 6 10 14 18 22Ft.
1 0 1 2 3 4 5 6M

FEBRUARY 15, 1908
REVISED SEPT. 1, 1908

Drawn by
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shafts of the Wallkill and Moodna siphons have been done by timbering methods, as preferred by the specifications. Some difficulty was encountered in the Wallkill drainage shaft, due to a small amount of seepage softening the clay locally, causing it to run out underneath. Most of the timbering has been successfully removed and concrete placed as contemplated directly against the earth.

Construction Shafts.—Plate 43 shows the standard minimum-sized construction shaft for rock without difficult overlying earth. The prescribed essentials are two cageways, a pump, pipe and ladder well, two boxes for protection of plumb wires, close sheeting and timber sets not more than 6 ft. centers vertically. The shaft is paid for by the foot, and the contractor may make it as much bigger as he likes, but no smaller. This provision insures what was thought to be an adequate shaft and at the same time makes a liberal-sized shaft stand or fall on its own financial merits.

The first contractor made the cageways 6 ft. 5 in. by 8 ft. 0 in. instead of 4 ft. 5 in. by 5 ft. 6 in., and the rest have followed suit. The writer was not surprised at this, knowing the tendency of general contractors to use shafts that would be considered liberal even for most mines.

The adequacy, in size, of the contract design has been questioned, and a statement of the reasons for thinking it adequate, though not necessarily most economical, is pertinent. The Catskill Aqueduct siphons are not mines with enormous quantities of ore or coal coming from many levels, but are merely drifts extending only about 2 000 ft. on each side of the shaft—that is, only four or five times the depth of the shaft. 80 000 cu. yd. of muck and 20 000 cu. yd. of concrete and other material is to be handled through each shaft, in, say, twenty-four months. This makes an average of 170 yd. per day, or about 7 yd. per hour, to be handled by two cages—a mere fraction of what is handled by many mine shafts no larger than that shown in the contract design. The contract design was planned to accommodate a stock mining car 36 in. by 58 in. over all, standing 46 in. high, holding 21 cu. ft., and dumping either side or end. The cage will also easily carry a mining mule of ordinary size. The contractor's design costs about $12 000 more per 500-ft. shaft (including concrete plug and back filling) than the engineer's design, and hence, to justify itself must result in about 12 cents economy on every yard of material moved into or out of

the tunnel. In estimating the difference in cost of the two sizes of shafts, the excavation in the larger one was assumed to cost \$16.60 per yard, and in the smaller one \$18 per yard, the larger one being thus given all the benefit in reduced unit cost due to larger size that was shown to be proper by what records are available.

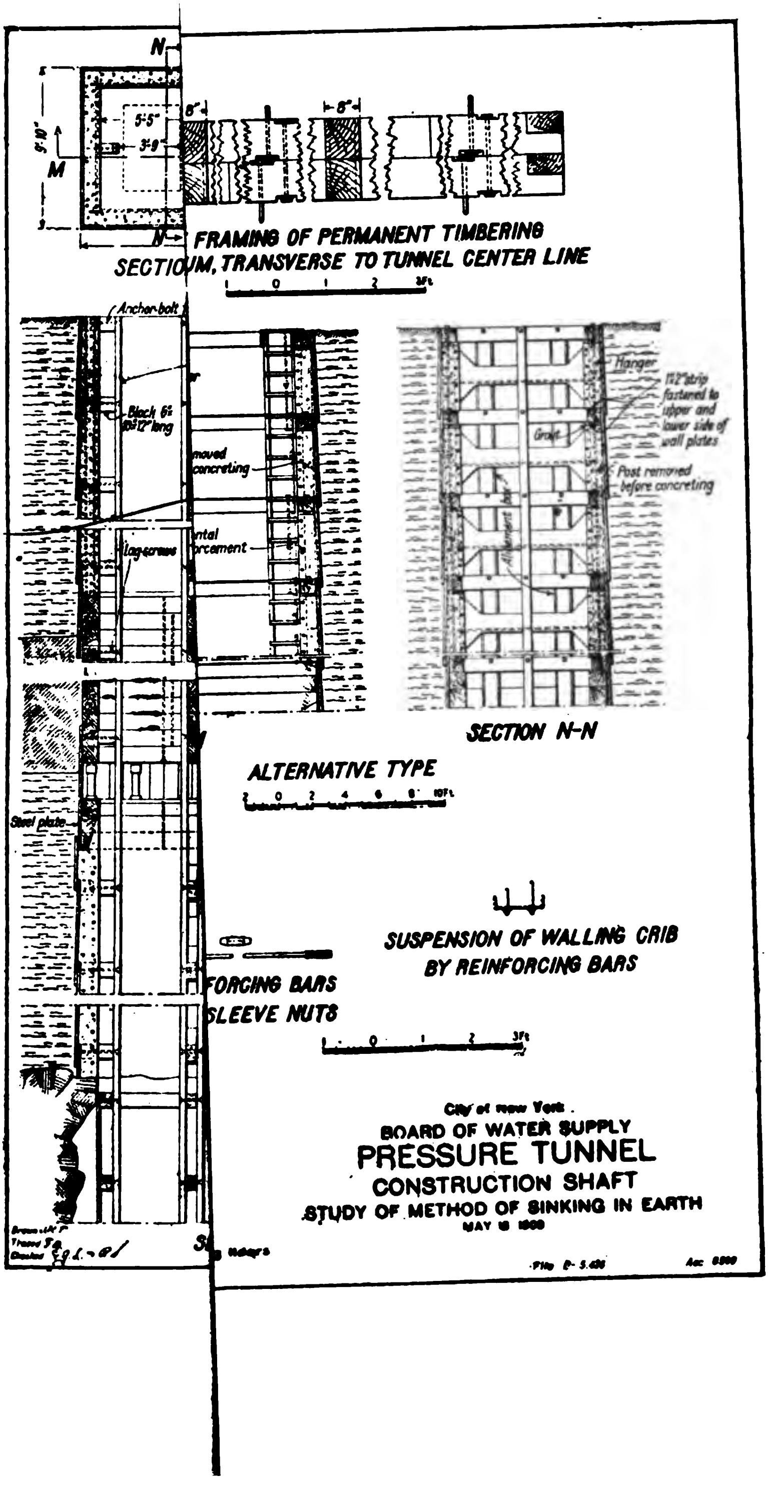
Construction Shaft Closure.—The design calls for "concrete filling from 25 ft. to 50 ft. in depth, according to character of rock and flow of water." 25 ft. gives a shearing stress on the concrete and rock at the edges of the periphery of the shaft of about 40 lb. per sq. in. for the head, 718 ft., at the deepest Rondout shaft, measured from the hydraulic gradient to the bottom of the plug. Note the grouting channels to be formed around the shaft about every 6 ft. in height, in order to enable the shrinkage space around the plug, if any under such damp conditions, to be filled up. Note the grouting well, left to permit short pipes in grouting the channels and any seams in the rock. Note that the shafts are not generally to be entirely refilled, but the timber left in and an arch turned in sound rock near the top to cover the shaft and support the filling for the upper part of the shaft.

Construction Shafts Through Deep Earth Cover.—Plate 44 shows a study for a deep construction shaft in earth, such as shaft 2 of the Moodna siphon, 100 ft. deep. The modern tendency at mines seems to be to employ a firm of specialists, such as The Foundation Company, for deep earth shafts, these specialists using a drop shaft with air pressure after about 40 ft. done in open caisson. Many of these shafts in this country are at iron mines near the Great Lakes, where the "overlie" is soft and wet. For such locations drop shafts have been a blessing, but in the unmodified drift occurring in most parts of the region traversed by the Catskill Aqueduct, drop shafts are usually unnecessary. The plate shows a design made to permit this shaft to be sunk without a drop shaft, resort being had to a jacking caisson, if necessary. The shaft in question at the Moodna was started as a drop shaft and at last accounts, the attempt was being made to dislodge the caisson by blasting around it. The caisson will perhaps be safe and successful, but will probably prove unnecessary.

Drainage of Pressure Tunnels.

To drain or not to drain the pressure tunnels has been a question considered frequently by the engineers of the Board of Water

PLATE 44.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



Supply with about as much uncertainty of mind as is engendered by Hamlet's question. The Washington Aqueduct tunnel is drained almost yearly, but it is shallow. The Harlem River siphon has already had two drainage plants, but has never been unwatered. If one were confident that present-day Portland cement is absolutely permanent, no necessity for ever draining a pressure tunnel would exist with such clear water repeatedly screened before reaching a pressure tunnel. Plants for use never, or at most once a century, are not conducive to enthusiastic expenditure by conscientious engineers of the present generation. Not being able, however, to wholly eliminate the possible need, provisions for draining the pressure tunnels conveniently are being made at an expense of something less than a million dollars for all tunnels north of the Hill View Reservoir.

Plate 45 shows diagrammatically the accepted method, outlined first by the writer in 1906, but not adopted until every other type of plant available was studied and estimated upon by the mechanical engineering force under Mr. R. W. Steed.

The essential parts of the plant are as follows (see Plates 45 and 46):

1. The drainage shaft, with its drift connecting with tunnel. This is also used as a construction shaft so that only the difference is chargeable to drainage. Wherever possible, the drainage shaft is thus placed away from the tunnel and connected with it by a drift, thus bringing the cut-off between tunnel and drainage shaft in sound rock instead of at the surface as would be practically necessary with a drainage shaft over the tunnel.

2. In the drift a swinging bulkhead, or door, which shuts tight under pressure from the tunnel, being also bolted initially to compress the gasket in its groove to an even bearing and bring the flanges together.

3. A cylindrical steel float running on guides in the drainage shaft, and deep enough to float two multi-stage, motor-driven, direct-connected centrifugal pumps; also to support the discharge pipe.

4. A discharge pipe which is extended upward as the float goes down, and is braced laterally by light stiff trusses with their ends held by the same guides upon which the float runs. These guides are placed at the top at intervals on the pipe and go down with the pipe, as the float sinks.

5. A reel at the top of the shaft for handling the electric cable carrying current to the vertical pump motors.

6. An elevator, running on a separate pair of guides in the shaft, for service to the float and for maintenance purposes after the tunnel is unwatered.

7. A bronze check-valve at the bottom of the shaft on a pipe connecting with the tunnel. This valve closes with the pressure from the tunnel, and is so set that it may be operated by a weight let down from the surface through a vertical bronze pipe set in the concrete lining.

8. A smaller bronze valve on the side of the check valve, for letting water from the tunnel into the shaft by throttling in case it is preferred to unwater the shaft completely before draining the tunnel.

9. A lead-lined 16-in. cast-iron blow-off pipe set in the concrete shaft lining, connecting with the tunnel and gated at the top. This permits blowing off the water in the siphon down to the level of the ground at the drainage shaft—*i. e.*, draining the end shaft and removing considerable of the pressure. In connection with 10 it also serves to refill the shaft, if desired.

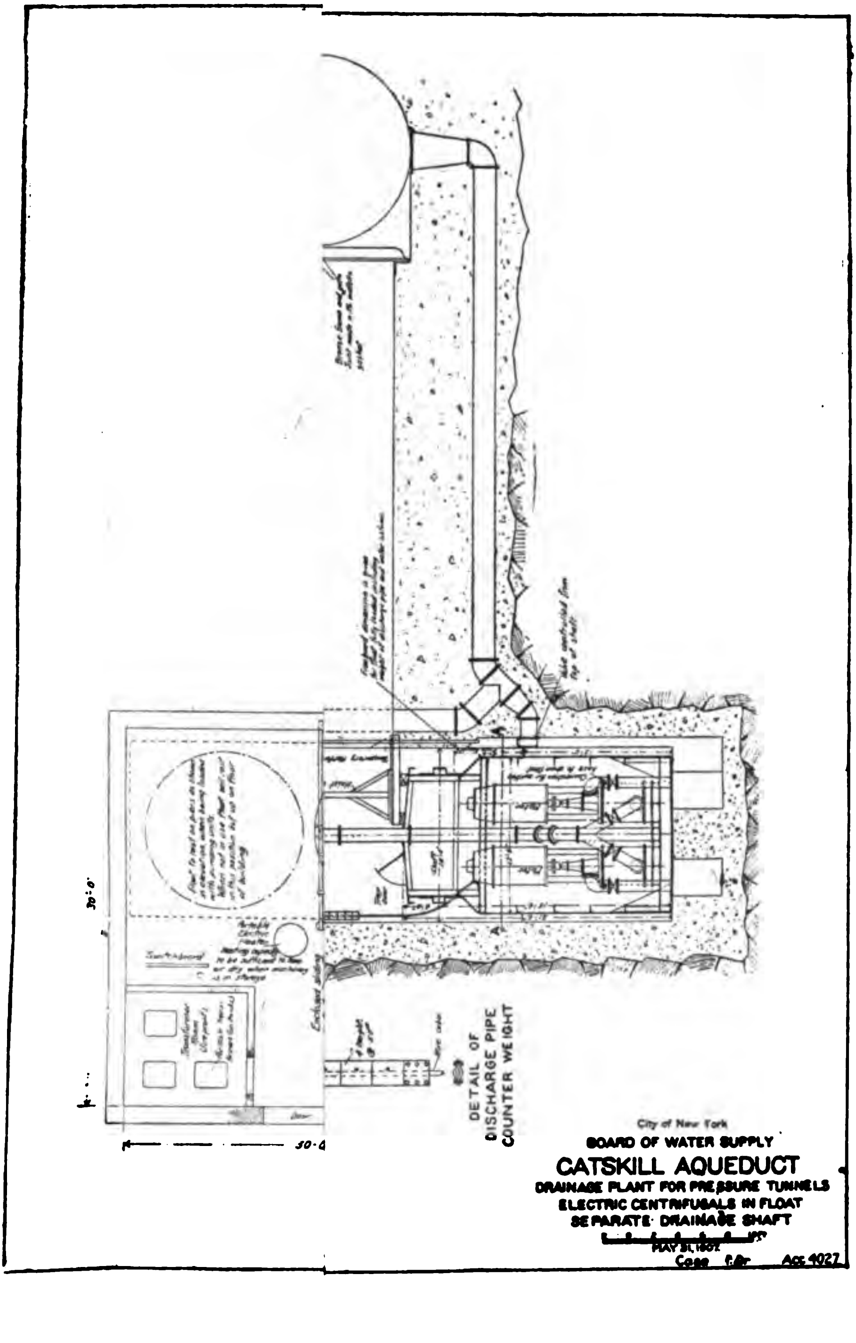
10. A concrete tank, with open top, placed in the drainage chamber and connected as follows: (*a*) with the blow-off pipe (9) through an 8-in. valve and c. i. pipe; (*b*) with the drainage space back of the inner lining of the shaft. This latter connection is of such size that when the tank is full sufficient water will pass through it, down back of the inner lining of shaft and into the bottom of the shaft, to raise the float at the rate of 4 ft. per minute. No greater speed can be obtained through this connection on account of the overflow. Hence the 8-in. valve need not be handled to a nicety but merely opened enough.

11. Transformers for reducing high tension current.

12. Crane for handling float and machinery.

Two essentially different methods of operation may be used in draining and two for refilling and bringing the float and machinery to the surface.

PLATE 45.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



Draining, Method A (to be called hereinafter "The simultaneous method of draining").

(*a.*) Remove floor of chamber, place float in recess adjacent to shaft, place pumps and motors in float.

(*b.*) Fill shaft (already full up to small overflow at invert of chamber) up to point necessary to suspend the float, using valve described under 10 above.

(*c.*) With aid of crane to steady and move the float, move it over the shaft so as to engage with the guides; then drain the shaft down again to the invert.

(*d.*) Blow off the tunnel to same elevation as shaft, *i. e.*, as far as possible.

(*e.*) Lower weight through bronze pipe onto check-valve to hold check-valve open. Its own weight may or may not have opened it already, as corrosion of the bronze may make it stick slightly.

(*f.*) Operate pumps, adding, as needed, lengths of discharge pipe, with their braces. When near the bottom inspection would naturally be made, by diver, or possibly through glass-covered peer-holes in bottom, of the masonry piers upon which the float will rest, to see if any tools or débris are present. The deck of float comes to rest at the proper level, and is to be used as a platform from which to enter the tunnel through the drift.

Draining Method B (to be called hereinafter "The seriatim method of draining").

(*a*), (*b*), (*c*) and (*d*) as in simultaneous method.

(*e.*) *Without* opening check-valve, operate pumps as in (*f*), "Simultaneous method," thus unwatering the drainage shaft but not the water-way shafts and the tunnel. The difference in heads between tunnel and drainage shaft will increase as the water level in the latter is lowered by the pumping. Whatever leakage takes place will tend to decrease this difference.

(*f.*) After pumps have come to rest, open throttling valve described under 8, p. 128, and drain tunnel into shaft as fast as the pumps can handle it.

For training a pumping crew, the seriatim method may be used without putting the aqueduct out of service.

Restoring Tunnel to Service, Method A (To be called hereinafter "The simultaneous method of filling").

(*a.*) Close and bolt access door between tunnel and shaft; also close throttle valve, if open, and temporarily close check-valve.

(*b.*) Let water slowly into tunnel, watching access door and valves for imperfect joints.

(*c.*) When satisfied as to joints, open check-valve by letting weight lowered through pipe from surface rest on it, and allow water level in shaft to rise with that in tunnel, thus avoiding unbalanced head on drainage shaft lining, but also putting regulation of the ascent of float into hands of those at head-gates of aqueduct.

(*d.*) When float is at top, remove weight from check-valve and allow it to close. The check-valve rod will be shaped so as to be easily grasped by well-drilling tools to aid in bringing it firmly on its seat.

Restoring Tunnel to Service, Method B (To be called hereinafter "The seriatim method of filling").

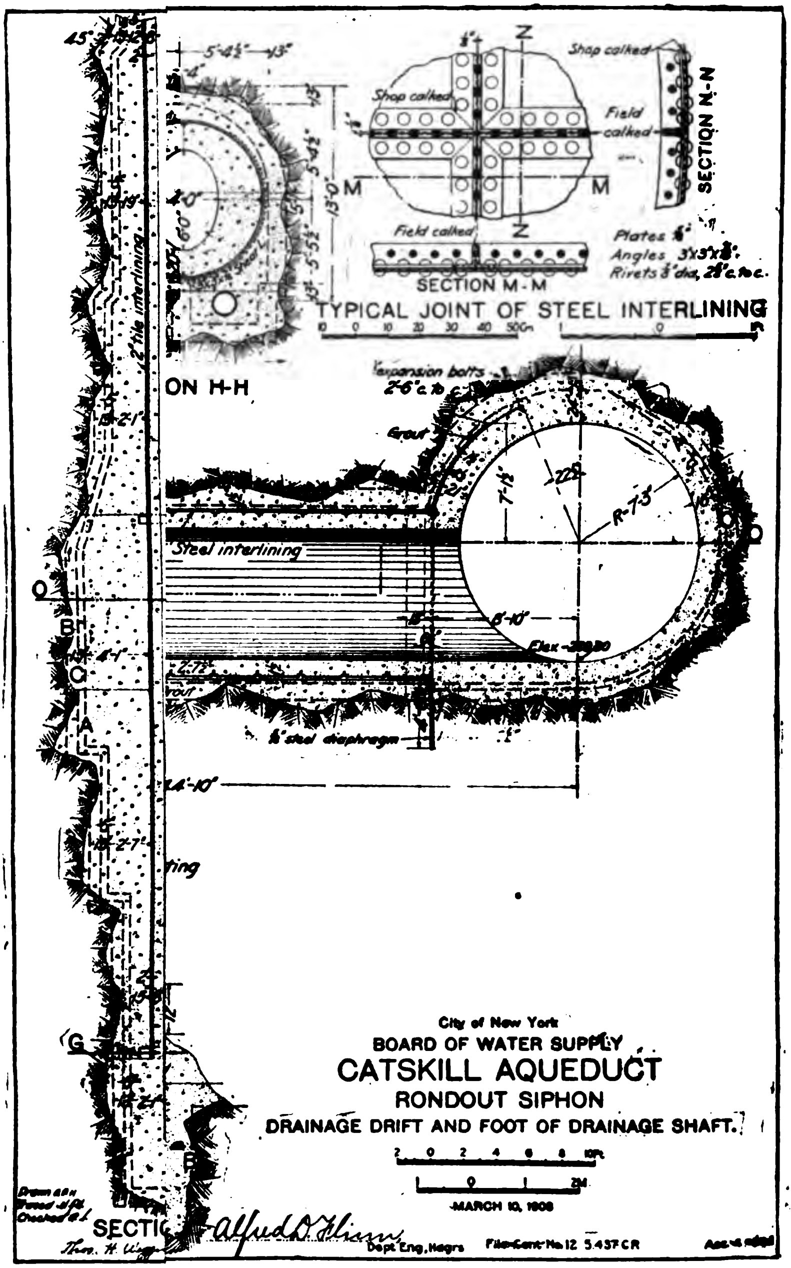
(*a.*) Close and bolt access door between tunnel and shaft, also close all valves.

(*b.*) Let water slowly into tunnel, watching access door and valves ready to stop filling immediately if there seems need of readjusting gaskets or of scraping valve seats.

(*c.*) After tunnel is filled to level of ground at drainage shaft, let water into concrete tank (10, p. 128) from which it will flow at a fixed rate down in the tile interlining to the bottom of the shaft, raising the float at a rate of 4 ft. per minute.

The main advantage in the simultaneous method of filling is as stated in (*c*), above, and the main objection in addition to that stated in (*c*) is the inability to leave all valves tightly and permanently closed. The check-valve was expressly contemplated for the purpose of permitting the simultaneous method of draining and of filling and hence eliminating the necessity of either an extraordinarily tight lining in the drainage shaft, such as could be produced only by using metal, or a double lining with drainage interlining. Mr. J. Waldo Smith, Chief Engineer of the Board was Chief Engineer of the Aqueduct Commission when attempts to pump down the drainage shaft of the Harlem River siphon were made, which were unsuccessful on account of accumulated leakage through the mortar joints of the cast-iron lining. He therefore stipulated that no similar risk be taken in the case of the Catskill Aqueduct

PLATE 46.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



drainage shaft, but accepted the writer's suggestion for a drainage interlining (which would carry leakage to the bottom of the shaft), in lieu of a tight metal interlining. The seriatim method of draining and of filling hence becomes possible and the check-valve ceases to be an indispensable adjunct. The simultaneous method of draining and the seriatim method of filling seem to the writer the most advantageous on the whole.

The most important feature of the drainage design is the closure in the access drift (Plate 46). The frame for the bronze door is backed by a steel casting and from it, both toward the tunnel and toward the shaft, is extended a structural steel interlining $\frac{5}{16}$ in. thick. There is also a structural steel cut-off diaphragm connected with the steel interlining and extended into a narrow channel cut into the rock 3 ft. beyond the general rock walls of the drift in a plane at right angles to the drift. Concrete is first placed outside of a form 3 inches larger in diameter than the outside of the steel lining. The drift is then grouted as if steel interlining were not to be used. The interlining is then placed in panels riveted together at inside flanges. The 1½-in. space outside of the interlining is next grouted and finally the internal concrete placed. The steel interlining compels the water to travel a long distance to escape. The writer regarded the *tunnel* side of the access door as the logical place to put the steel interlining, for the reason that a positive difference in head would be produced between water in the drift and water in the rock surrounding the drift, thus causing the drift lining to be forced against the rock like a cup-packing and making the filling of the arch over the drift the main source of uneasiness. The writer's idea in extending the steel into the tunnel *above* the top of the drift was to get some well-rammed concrete *across* the top of the drift excavation. The steel interlining on the shaft side of the door does not produce any cup-packing action. It was added as an extra precaution.

Drainage of Hudson River and Moodna Siphons.

The Hudson River and the Moodna siphons are practically one siphon as explained on page 110 and have one drainage point in common. On account of the comparatively great depth of the Hudson River siphon, and also on account of the necessity of sink-

ing the shore shafts for exploration purposes, it was planned to use the shaft on the easterly shore for the drainage shaft, as well as for a water-way shaft. This is instead of using the uptake shaft for drainage in the way adopted for the Croton Lake siphon (see p. 111; though in that case the downtake shaft was found more convenient than the uptake). The use of this shore shaft for drainage involves the boldest construction to be found in the work of the Board of Water Supply, viz., a removable cover for a shaft 14 ft. in diameter, to resist normally a head of about 400 ft. Plate 47 shows the design proposed by the writer in 1907 for this cover and appurtenances. The drawing is a study made to show that the closure is feasible. Improvements are in mind now but no other drawing is available and the principle is well shown by this one. The essential features are as follows:

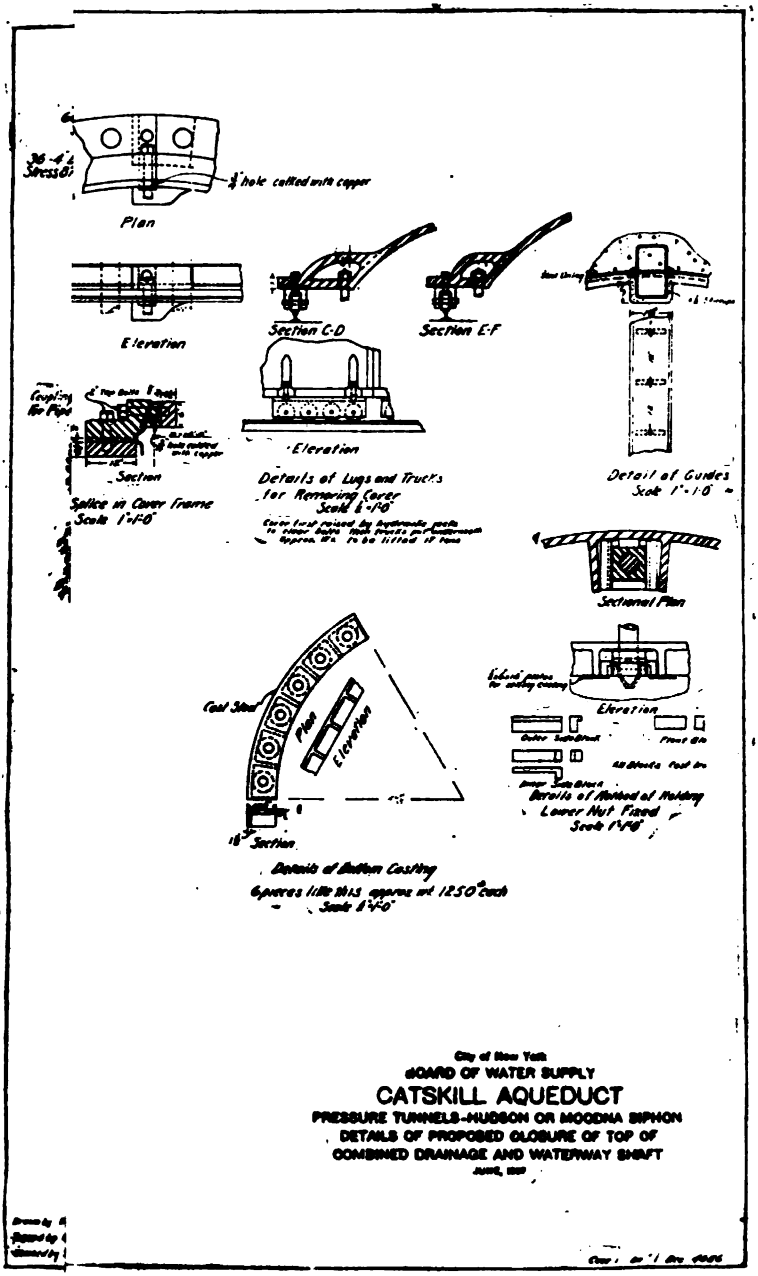
1. A plate steel interlining for the shaft, this interlining to be carried to the depth described on page 113 as providing sufficient rock cover to resist the upward pressure by dead weight alone. Below this, certainly, the tunnel pressure may spread into the rock without danger. The interlining, besides intercepting leakage, produces the cup-packing effect described on page 131 and thus assists in preventing leakage between the rock and the lining due to possible shrinkage of the latter.

2. A massive cast steel frame, in two parts to permit shipment by rail, attached to the steel interlining by a backed copper expansion piece and held down by thirty-six 4-in. steel anchor-bolts with screw ends upset.

3. A sectional cast steel anchor ring, sleeves for anchor bolts, and vaseline packing to fill the space between bolts and sleeves. The anchor ring is set at such a depth (about 60 ft.) that the rock above it, contained in an inverted truncated cone determined by a generatrix having a slope of 1 horizontal to 2 vertical and moving on the anchor ring as a directrix, has sufficient weight to counterbalance the upward pressure on the cover.

4. The cover, dome-shaped, of cast steel, and in two parts to permit shipment by rail. It is attached to the cast steel frame by sixty 3½-in. stud bolts. It is provided with out-board brackets under which small trucks can be placed running on fixed rails. To remove the cover it is first jacked up above the stud bolts, then the trucks inserted and the cover rolled back into a recess.

PLATE 47.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



The philosophy of placing the anchor-bolts in sleeves should be recorded. Bolts imbedded in concrete would, in stretching under the load, pull up the concrete and adjacent rock, producing horizontal and other cracks down to a depth necessary to furnish anchorage. The total movement would, of course, be small, say ⅛ to ¼ in., but enough to invite corrosion. The possibility of renewing the bolts is another advantage of the sleeve. The working stresses are as follows:

Cover (cast steel) 3 000 lb. per sq. in. (computed as part of a sphere).

Bolts (steel) 9 000 lb. per sq. in.

As both the cast and the bolt steel will have an ultimate strength of 60 000 to 75 000 lb. per sq. in., the design is manifestly conservative—much more so than those of great bridges or of boilers for steamships, or so far as the writer can recall of any other of the large metal structures, upon which so many human lives are constantly dependent. Furthermore, this Hudson River shaft is wholly in granite, at the foot of a rocky hillside and only about 75 ft. from the river. A safer place for an accident to occur could scarcely be found.

It has been planned to use the same plant for draining the Hudson River siphon as for the other pressure tunnels, coupling the two pumps (see Plate 45) in tanden after the Moodna has been emptied, which contains the greater part of the water and requires a lift of only about 200 ft. If the Hudson River siphon has to be placed much below 1 000 ft. a modification of this scheme will be required.

Closures of Moodna Siphon Access Shaft and City Siphon Shafts.—A design similar to that above described for the Hudson River drainage shaft closure is contemplated for the closure of an access shaft in the Moodna siphon about 700 ft. from the Hudson River on the West side (see Plate 33 and p. 110). This shaft is, however, only 8 ft. 8 in. in diameter which makes the design look much less bold. The Moodna design is included in a contract (No. 20) and contains improvements in detail not in the Hudson River siphon design here shown. Nickel steel having an ultimate strength of 80 000 lb. per sq. in. and an elastic limit of 50 000 is specified for bolts, and the working stress assumed is 12 000 lb. per sq. in. (actually computes 10 750 for the commercial size selected).

At least one closure similar to the Moodna access shaft closure, and probably about 11 ft. in diameter, also many closures 4 ft. or more in diameter will be required on the City siphons described briefly on page 111. The same essential features are being adopted in the designs for the larger of these closures; for the smaller ones the metal interlining is made to take the load from holding down the cover, and the surrounding concrete is reinforced by vertical rods to prevent the cracking above mentioned, and also to make a strong column to resist shocks from possible future operations in the adjacent ground. Bronze is to be used in the City siphons for all essential metal parts that are necessarily exposed, such as the anchor ring, tops of anchor bolts, tees placed at tops of shafts for connections to the distribution system, and shut-off valves next to the tees.

Full Capacity Blow-offs at Certain Pressure Tunnels.

At the Hudson River and at the Croton Lake siphons, it is planned to put a blow-off capable of taking the full capacity of the aqueduct, so that not only can the aqueduct be emptied quickly for maintenance purposes but also the whole flow can be diverted in a few moments in case of a break below either blow-off, and no more water allowed to flow down the aqueduct past the blow-off. This object is easily accomplished in the two cases by providing a blow-off outlet in a water-way shaft at a sufficient depth to discharge the full flow of the aqueduct when the water surface is below the invert of the grade aqueduct on the down-stream side of the siphon. It will be evident on thought that the mere placing of any number of large gates in the side of the grade aqueduct near the bottom would not intercept the flow, but that a depression is needed in the aqueduct. This depression is conveniently furnished by the siphons, and in Hudson River and Croton Lake siphons the large body of water necessary to take the full discharge is also available. Mr. F. P. Stearns, Consulting Engineer, was responsible for the general idea of these blow-offs.

The blow-off at Croton Lake consists as follows:

1. An outlet 5 ft. square, with rounded edges, in the downtake shaft at a depth of 71 ft. from the invert of the grade aqueduct at the shaft (or, what is more to the point, 67 ft. below the elevation of the invert of the grade aqueduct at the uptake shaft).

2. This outlet is tapered to 60 in. in diameter and 60-in. hydraulic valves in duplicate are placed in tandem at this point. The cylinders of these valves are proportioned to operate the valves with the head existing when the blow-off is in use. There would hence be available an excess head (reckoning to the normal flow line of the aqueduct) of about 19 ft. under the conditions that would exist when it would be desired to open the valves. There is also a hand pressure pump for use in case a valve should stick. The valves are in duplicate so that first one and then the other may be opened and shut, thus permitting frequent tests without blowing off.

3. From the valves the blow-off conduit is enlarged on Venturi meter lines to a 6-ft. horseshoe whence it pitches steeply down to Croton Lake on slopes of 0.04 to 0.31. The parts steeper than 0.04 are made higher, viz., 8 ft. 0 in., to prevent "down-draft" by exhaustion of air, and a large vent is placed at the upper end of this steeper stretch. The maximum velocity through the valves when first opened is about 72 ft. per sec. and the corresponding rate of discharge (existing only momentarily) is about 1 400 cu. ft. per sec. A rate much in excess of the flow in the aqueduct would be sustained for quite a while, as water from the aqueduct comes at first from both upstream and downstream.

For the blow-off at the Hudson River it is not yet decided whether to duplicate the Croton Lake design, placing the valves in the uptake shaft, which is about 800 ft. from the river, or to place one or more valves at the drainage shaft, which is only about 75 ft. from the river. These latter valves would discharge under a head of nearly 400 ft. and their counterpart for such large quantities is not known to exist. The water power dissipated at the shore shaft when the blow-off is operating at full capacity would be about 40 000 h.p.

Junction of Bryn Mawr Steel Pipe Siphon and Yonkers Pressure Tunnel,

165 ft. below Hydraulic Gradient.

Plate 34, already referred to on page 111, shows the single case so far existing on the Board of Water Supply work, of steel pipes and a pressure tunnel forming together what is practically one siphon, the junction being 165 ft. below the hydraulic gradient. The design consists essentially, as would be expected, of carrying

the steel pipes far enough into the rock beyond the tunnel portal to insure against leakage. For reasons which will become evident, three separate smaller tunnels are driven, into which to seal the steel pipes, the three converging beyond the steel pipes into the single 16 ft. 7 in. tunnel of the Yonkers siphon. The steel pipes where in the rock, do not need thickness corresponding to the pressure, since the weight of the rock over the pipes, at the portal, reckoned between slopes of 2 vertical to 1 horizontal, is sufficient to hold down the pressure. The steel pipes are carried into the rock to the point where the dead weight of rock, reckoned between vertical planes, would hold down the pressure over the whole horizontal projection between these vertical planes. This would permit that the water should spread out horizontally indefinitely with undiminished pressure and still not lift the rock, and will be recognized as the same conservative principle as was adopted for the Hudson and Moodna siphon designs (see pp. 113, 132 and 133).

In the rock the steel pipes will be interlinings surrounded by grout and concrete and lined with concrete, the construction being like that adopted for the drift between drainage shaft and tunnel in the Rondout and Wallkill siphons. Just outside the tunnel on each pipe line is a 60-in. hydraulic gate placed in a Venturi-meter-like reduction. The velocity through these gates at time of maximum flow in the aqueduct is about 18 ft. per sec.

Just before the three branch tunnels converge into the main tunnel a recess is placed in each, so that a temporary bulkhead can be placed, thus permitting the steel interlining to be repaired in one branch tunnel, the aqueduct remaining in service except during the few hours necessary to place the bulkhead.* The drawing shown is merely a preliminary study. Instead of having piers to divide the bulkhead spans, as shown, the branch tunnels may be made elliptical. This has the added advantage of making simpler the transition from three branch tunnels into one main tunnel. When not in use the water-way at the recesses may be made smooth by easily removable masonry.

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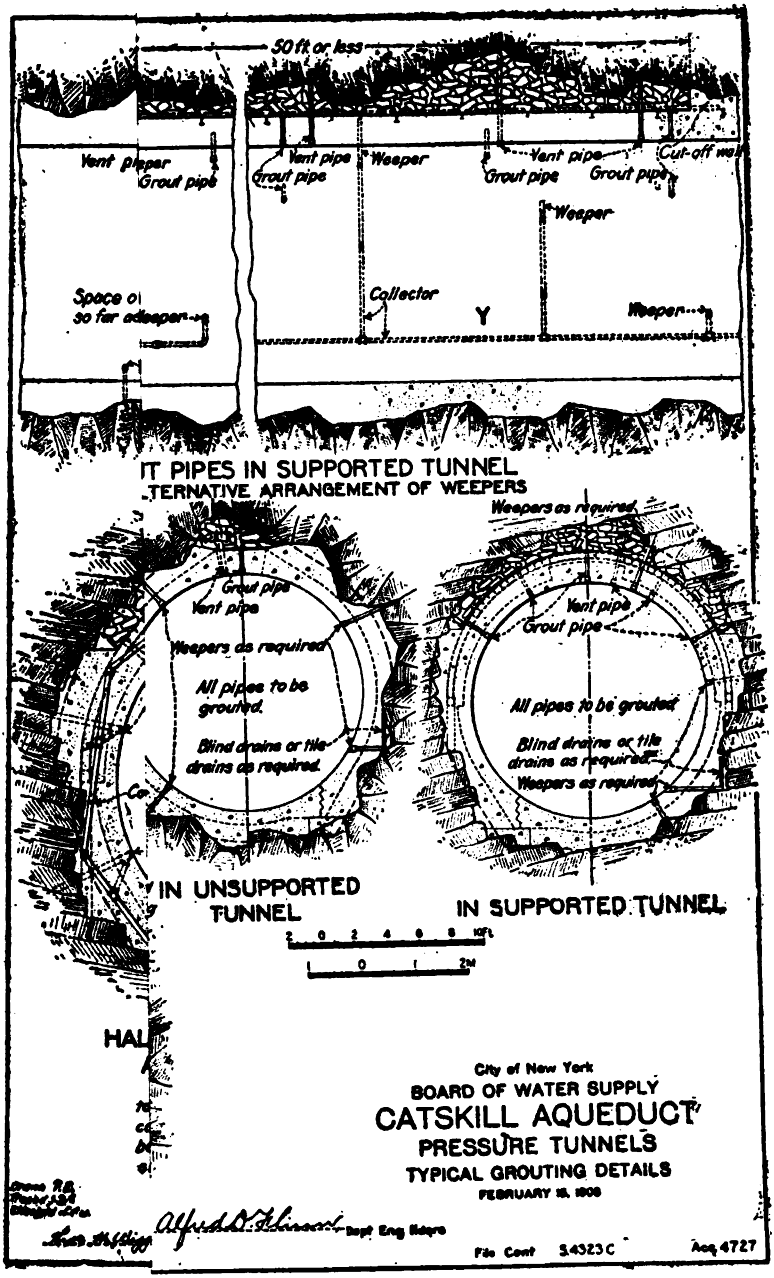
*The steel construction is the same as at other places referred to and no more liable to corrosion, but the aqueduct north of Kensico reservoir is much less critical in maintenance on account of the large storage in Kensico reservoir. The maintenance of the city siphons can be satisfactorily solved only by duplicating the siphons. The designs will be even more massive than elsewhere and renewals should certainly not be necessary until a second tunnel is needed for the consumption.

PLATE 48.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



Methods of Grouting and of Handling Water During Concreting and Grouting.

The problem of grouting is inseparable from that of taking care of incoming water during concreting. All such water must be kept from the fresh concrete and carried through the forms in pipes, through which grout should afterwards be forced with sufficient pressure to overcome the ground-water head and displace the ground water for a considerable distance from the tunnel. The filling of voids around timber and steel support and over the arch is an important function of the grout, making for permanence, stability and greatest tightness, but in dry, impervious rock, the omission of such grout would not be a calamity, especially if weepers were constructed to equalize the pressure on the inside and outside of the lining; whereas the grouting of crevices and holes in the rock through which ground water enters is of the utmost importance, since water can escape wherever it can enter and in much greater quantities because the unbalanced heads are much greater.

Plate 48, from a drawing made under the immediate direction of Mr. L. P. Wood, shows in a typical way the most important conditions to be met with and methods for use in grouting and handling water in the pressure tunnels. It will be noted on the drawings of tunnel sections, Plate 35, that the space over the minimum arch is "to be filled with concrete or with dry-packing as ordered." Authorities differed as to which way was better, and it is hoped to decide after stretches of tunnel have been done each way and inspection holes have been cut as provided in the specifications. The two methods as related to grouting are shown adjacent in the upper left-hand corner of Plate 48. It is recognized that it would be too expensive, if not impossible, to fill the higher voids with concrete, and vent and grout pipes are set to complete the filling. The writer would be inclined to deliberately leave a small but continuous void all along over the arch even in this method of so-called filling the spaces with concrete.

Note the cut-off walls extending to the roof every 50 ft. or so in all types of tunnel, in order that the tunnel may be grouted in short stretches and not by letting the grout follow its own whim in spreading from any hole to other parts of the tunnel. The

experience of Mr. Ridgway in the Battery tunnel is directly responsible for this provision.

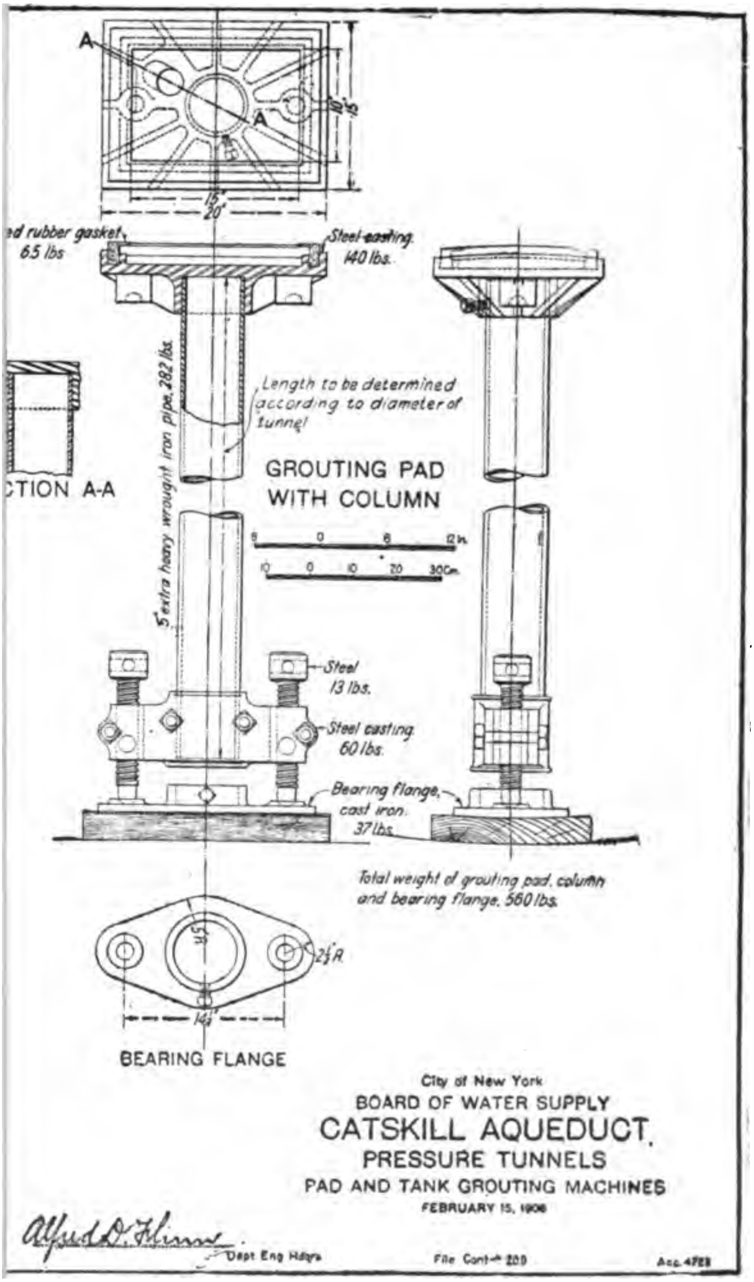
The expected use of steel forms accounts for the complication of certain of the typical details shown, these being a suggested method to make unnecessary either special wooden panels wherever a weeper is required, or the cutting of many holes through the steel forms at such places. The design consists of a system of collectors back of the forms with a few regular holes in the forms. As it is desired to grout each leak in the rock separately, and through a short, direct pipe, each leak requires one connection direct to the surface of the form and another to the collector. Note the Y's for accomplishing this in the system shown in the lower left-hand corner. By plugging collectors through these Y's, they may be grouted first so as to permit the separate grouting of each leak. Special suggestions are shown for grouting around the steel diaphragm and interlining in the drainage drift, Rondout and Wallkill siphons.

Note the blind drains and metal drip-pans for keeping the water from the concrete and concentrating it in the weepers. Only an ingenious, resourceful man should have charge of grouting and handling water, as each situation requires its own treatment.

Plate 49 shows the so-called "tank grouting machine" for mixing and ejecting the grout, and the so-called "pad grouting machine" for permitting grout to be forced into porous lining. In the tank machine grout is mixed by turning air in at the bottom and ejected by turning air in at the top. There are no stuffing-boxes and shafts of revolving stirring devices to wear out by grinding in cement, and the machine weighs only 500 lb. empty, though designed to stand 600 lb. test pressure. The design is substantially that of Mr. W. L. Caniff, who had charge of the very successful grouting of the Cincinnati tunnel. It has been used in the Steinway and Pennsylvania tunnels in New York. The grouting pad is also substantially that of Mr. Caniff, based on successful experience with cruder devices in the Cincinnati tunnel.

To overcome ground-water head exceeding the normal air pressure used in drilling, small Westinghouse type compressors are specified, which are to be operated by the ordinary air pressure and be each capable of supplying per minute 2 cu. ft. of air at 300 lb.

PLATE 49.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



per sq. in. The weight of each machine, including stand and carrying hooks, is not to exceed 550 lb.

Evidence Available as to the Success of Grouting.

The strong reliance that is placed on grouting by methods above described make pertinent a statement of the evidence upon which the faith is based. Grouting is often done in engineering works but the results are seldom possible of inspection. The following cases form the basis of the writer's faith:

(*a.*) Mr. Horace Ropes examined the grout exposed a few years ago in opening a shaft of the Croton Aqueduct for connection with Jerome Park Reservoir. He reported excellent filling over the tunnel arch and in the interstices of the dry-packing. This was presumably natural cement grout.

(*b.*) Mr. Robert Ridgway and Mr. F. C. Noble reported excellent filling of the dry-packing between the rock and the cast-iron lining removed a year or two ago in straightening the Battery tunnel. Where the tunnel was in earth the grout was present over only a part of the surface, as would be expected. The grout was 1 cement to 2 fine crusher screenings.

(*c.*) Mr. Ridgway states that on Joralemon Street, Brooklyn, in the Battery tunnel work, grout was forced up through the ground and floated the pavement in spots. When digging a shaft down to tunnel already grouted, the grout was found filling minute crevices in the earth way to the surface.

(*d.*) Mr. E. F. Bradt sunk a very difficult shaft in Detroit by the aid of grouting. Open seams up to 1 foot thick, with an almost limitless supply of water, and other water-bearing voids were stopped by forcing grout through drill holes. The grout had to overcome and drive back the ground water, which was under heads of from 200 to 450 ft.. The writer has visited this work.

(*e.*) Following the methods of Mr. Bradt, Shaft No. 4 of the Rondout siphon was rendered workable by forcing grout through borings into the porous rock.

(*f.*) The Cincinnati tunnel was rendered almost bottle-tight by grouting by just the method proposed for the Board of Water Supply work.

The only failure the writer knows of is the Torresdale tunnel, in which case only one-eighth of the leakage was cut out by systematic grouting. Here the grout did not stay in the rock but came back into the tunnel through leaks.

Special Features of Specifications.

The specifications are worthy of examination as providing what are hoped to be unusually fair methods of payment, eliminating the gambling element in so far as is practicable. Thus all water necessarily pumped from the siphons during construction is paid for at a bid price per million gallons raised one foot high. Steel roof support must be kept on hand in ordered amounts to avoid delay, but the City pays a bid price for any left over. Grouting is divided, for payment, into its elements, this requiring 8 items, viz., 1 item each for the tank and pad grouting machines and the high pressure compressors (these becoming the property of the City and subject to transfer to another job at any reasonable time); 1 item for miscellaneous plant such as piping, trackage, etc., 1 item each for connecting machines to a pipe in the masonry and setting up grouting pads against the lining (each ordered connection or set-up being 1 unit under the items); 1 item for grout sand which is especially fine, and 1 item for mixing and placing the grout, the unit being the cubic yard. Therefore in making a bid the contractor does not have to know in advance how many leaks there will be, or how much supported ground, or the grouting mixture, or how many times the engineer will order a hole to be re-grouted, or, in fact, anything except the nature of the work. The plant charges being largely covered by explicit items, it is not necessary to know the quantity of work, which is impossible of prediction. The method seems a little complicated on first thought, and contains items for which the contractor has no precedent for estimating costs. The method possibly results in increasing the total cost of grouting, but the work is too important to run risk of hampering the engineers by insufficient methods of payment; and the City policy does not permit the work to be done by force account.

The numbering of sections in the specifications constitutes a departure from usual methods. The method will be most quickly understood from the following explanation contained in each specification:

"In numbering the sections of the specifications, the decimal system is used, the figure before the decimal point indicating the item number, and the figure after the decimal point the serial number of the section under the particular item. Where several items are grouped together, as Items 1 and 2, the number of the first item of the group is placed before the decimal point, as 1.1, 1.2, 1.3, etc. The general sections have no decimal points."

This method was suggested by the writer, mainly as enabling final numbers to be given to sections as soon as the list of items is established, thus doing away with that vexing and burdensome revision of section numbers throughout the balance of the document every time a section is added or removed. It has the additional advantage that it gives a quick clue to all cross-references, since one soon comes to know the item numbers; and it gives the sections of standard items the same decimal number in whatever contract they appear, thus minimizing the changes in making up new contracts, and aiding the memory in recalling cross-references.

The designs herein described were made by two squads of about five men each, led by Mr. Leonard P. Wood and Mr. Russell Suter, reporting directly to the writer, who reported to Mr. Alfred D. Flinn, Department Engineer, Headquarters, and he in turn to Mr. J. Waldo Smith, Chief Engineer. Messrs. John R. Freeman, William H. Burr, Frederic P. Stearns and Arthur West, Consulting Engineers (the latter on mechanical work), advised on the work. Mr. R. W. Steed, and latterly Mr. Horace Carpenter, Mechanical Engineer, Mr. Arthur Underhill, Landscape Engineer, and Mr. H. Lincoln Rogers, Architect, all attached to Headquarters Department, attended in co-operation with the writer to the various matters coming within their respective provinces. The surveys, sub-surface explorations, and locations were made by the Northern and Southern Aqueduct Departments under Messrs. Robert Ridgway and Merritt H. Smith, respectively, Department Engineers.

APPENDIX 1.

Summary of Typical Steel Pipe Siphon Estimates,

Such as were used in comparisons with pressure tunnels, to determine in any case which type of valley crossing was more economical. Given to show maintenance, renewal and deferment factors in steel pipe estimates, not necessary in pressure tunnel estimates.

For a Certain Siphon.

Cost of 1 line of pipe in service 1913	\$1 508 000
Maintenance and repairs, at \$250 per mile per year, \$1 120. Fund at 4% interest	28 000
Fund which, put at interest at 4% componded semi-annually, will amount to itself + \$1 508 000 in 75 years, and hence may be used to renew the pipe indefinitely: *.0541 × \$1 508 000 . . . . =	82 000
Present cost of 1 line indefinitely maintained and renewed	\$1 618 000
Present cost of 2d line in service 1920 = 0.700 × \$1 618 000 . . . . =	1 133 000
(*i. e.*, 70 cents put now at 4% compounded semi-annually will amount to \$1 by the time payments are due on pipe which will be needed for service in 1920.)	
Present cost of 3d line in service 1929 = 0.490 × \$1 618 000 . . . . =	793 000
Total present cost of 3 lines indefinitely maintained and renewed	\$3 544 000
(To which must be added cost of land, cost of two siphon chambers, and cost of any other structures needed to bring the termini of the steel pipe siphon to the same stations as those assumed in computing the pressure tunnel cost.)	

The pressure tunnel estimate is a straight estimate of the cost of constructing the whole siphon at present and assumedly so permanently as to make maintenance and renewal charges negligible.

* Formula: $x\,(1.02)^{2n} = 1 + x$. If $n = 75$, $x = .0541$.

APPENDIX 2.

Demonstration of the Writer's Parallel Tangent Theorem

For Obtaining the Most Economical Ratio of Sizes for Various Types of Aqueduct.

Let the three curves, shown in Plate 50, marked Type 1, Type 2 and Type 3, represent the properties of three types of aqueduct, such as Cut-and-Cover Aqueduct, Grade Tunnel and Pressure Tunnel. For each curve the ordinate at any point represents the slope at which the size in question will carry the quantity of water for which the aqueduct is being designed. The abscissa at any point is the cost per unit of length, this cost of course being greater for flatter slopes. The curves are generally constructed by plotting slopes and costs for certain definite sizes of aqueduct. On the curves the smallest sizes given are marked, respectively, D_1, D_2 and D_3 for the three types, and the larger sizes are marked $D_1 + 1$, $D_2 + 1$, $D_3 + 1 \ldots\ldots D_3 + 3$.

Let L_1, L_2 and L_3 be the total lengths of the three types, respectively, in the whole aqueduct.

Let dS_1, dC_1, etc., represent infinitely small changes in slope and corresponding changes in cost per unit of length.

Then:

(*a*) $L_1S_1 + L_2S_2 + L_3S_3$ must equal the total fall available for loss of head in aqueduct exclusive of special structures.

The cost is not a minimum so long as the slope of 1 type can be increased and of another diminished so as to keep the same total fall but decrease the cost; that is, at the point of minimum cost such corresponding changes in slope, if infinitely small, do not change the cost. Expressed by formula,

(*b*) $dC_1 \times L_1 = dC_2 \times L_2$;

also (*c*) $dS_1 \times L_1 = dS_2 \times L_2$ (in order that total fall may not be changed).

(*d*) or $L_2 = L_1 \times \dfrac{d\,S_1}{d\,S_2}$.

Substituting L_2 as obtained in (*d*) for L_2 in (*b*)—

(*e*) $d\,C_1 \times L_1 = d\,C_2 \times L_1 \times \dfrac{d\,S_1}{d\,S_2}$;

or $$\frac{d\,C_1}{d\,S_1} = \frac{d\,C_2}{d\,S}. \text{ But } \frac{d\,C_1}{d\,S_1} = \text{Cot. } \theta_1 \text{ and } \frac{d\,C_2}{d\,S_2} = \text{Cot. } \theta_2;$$

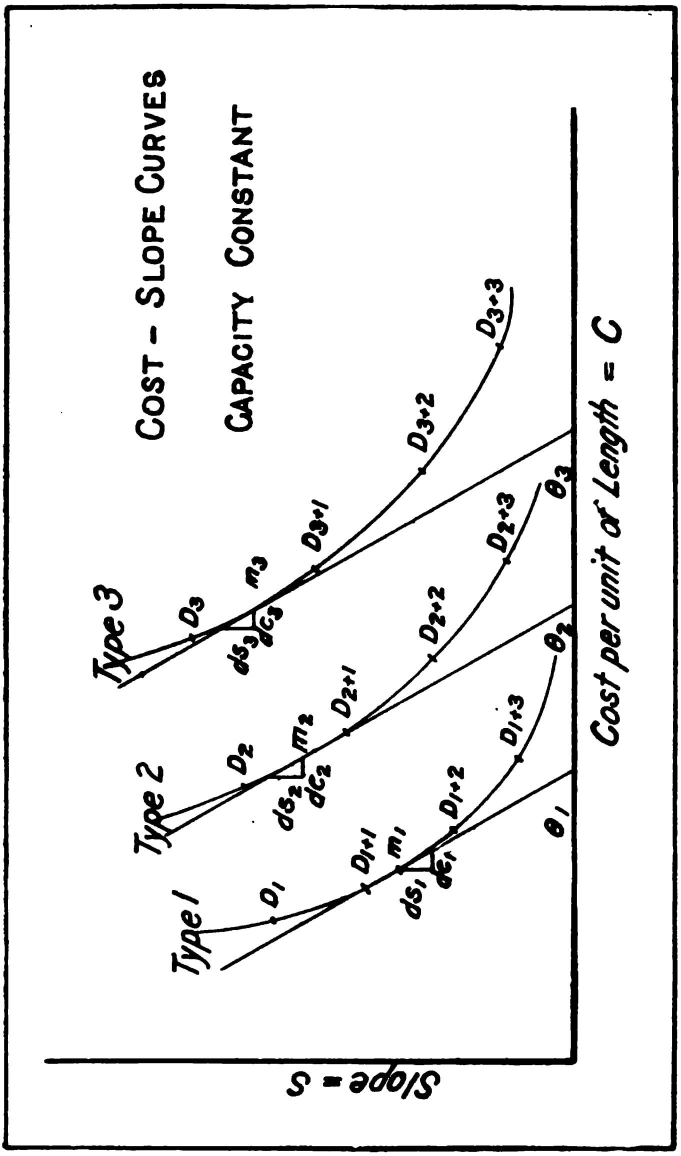
hence (*f*) $\theta_1 = \theta_2$.

It is further evident that $\theta_1 = \theta_2 = \theta_3 = \theta_n$, otherwise a change producing economy could be made between the type having a different θ and any of the other types.

This proves the very simple theorem that under the assumption that curves are correct and lengths do not change perceptibly with change in relative slopes, the sizes of various types giving least cost for the whole aqueduct are such that tangents, θ, to the cost-slope curves are parallel and the total fall is used up, as shown in equation (a).

This theorem saved almost countless trials of different combinations of slopes for the various types to discover the most economical. It was used equally well even if one type was fixed in slope, or if a relation between slopes of certain types was fixed. The latter case was solved by drawing a composite curve of the two types, weighting each type in the composite according to length.

PLATE 50.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
WIGGIN ON DESIGN OF CATSKILL
AQUEDUCT PRESSURE TUNNELS.



N b	References.
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....	*E. N.*, Feb. 27, 1907; Oct. 18, 1900; July 5, 1890.
....	*Transactions*, Am. Soc. C. E., Vol. 12, 1883.
....	*Transactions*, Am. Soc. C. E., Vol. 10, 1881.
....	*E. N.*, Feb. 27, 1907; Nov. 8, 1900.
....	Wegman's "Water Supply of the City of New York." Aque. Comm Reports. *Proceedings*, Engrs. Club, Philadelphia, Dec., '89. B 5.36 Cn/VE 290-2 — VE 148-9.
....	Same as above.
and 1895...	Reports Ch. Engrs. U. S. A., '84, '86, '89, '95, '01. House Document No. 186, 54th Congress, 1st Session. Senate Report No. 2686, 50th Congress, 2d Session. Acc. 5475. B 5.4228/U 244, 298-5, 202.
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ed in passage	*E. N.*, Feb. 27, 1907; *E. R.*, June 16, 1898; *Engg.*, June 4, 1898.
....	*E. N.*, Feb. 27, 1907, City reports.
el sideways	Prelini's Tunneling, p. 280; *E. N.*, Oct. 25, 1890; Sept. 19, 1895.
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ith 90' cover, broke in.....	*Eng. and Ming. Jour*., Nov. 18, 1905.
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....	Letter, Jos. Daniels to G. T. Seabury, May 10, 1908. B. W. S. files.
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APPENDIX 4.

PRESSURE TUNNELS—THICKNESS OF LINING.

Application of Theory of Thick Hollow Cylinder.

Symbols

R_1 = Inside radius of cylinder.
R_2 = Outside " " "
X = Radial distance to point at which stress is desired.
T = Thickness of cylinder wall.
P_1 = Intensity of internal pressure.
P_2 = Intensity of external pressure.
S_x = Intensity of tangential stress at point distant X from axis.
S_1 = Intensity of tangential stress at inside fibre.
S_2 = Intensity of tangential stress at outside fibre.

Lamé's Formula.

From Merriman's "Mechanics of Materials," 9th edition, p. 310:

$$S_x = \frac{R_1^2 P_1 - R_2^2 P_2}{R_2^2 - R_1^2} + \frac{R_1^2 R_2^2}{R_2^2 - R_1^2} \cdot \frac{P_1 - P_2}{X^2} \quad \text{........(1)}$$

External Pressure Only ($P_1 = 0$).

Inside fibre stress ($X = R_1$),

$$S_1 = -\frac{2 R_2^2 P_2}{R_2^2 - R_1^2} \text{ (Compression)........ (2)}$$

Neglect these minus signs in all subsequent computations.

Outside fibre stress ($X = R_2$),

$$S_2 = -\frac{R_2^2 + R_1^2}{R_2^2 - R_1^2} P_2 \text{ (Compression)......(3)}$$

Maximum fibre stress is at inside fibre, $S_1 > S_2$.

Internal Pressure Only ($P_2 = 0$). (Not often used in pressure tunnel design but given for completeness.)

Inside fibre stress ($X = R_1$).

$$S_1 = \frac{R_2^2 + R_1^2}{R_2^2 - R_1^2} P_1 \text{ (Tension)..........(4)}$$

Outside fibre stress ($X = R_2$).

$$S_2 = \frac{2 R_1^2 P_1}{R_2^2 - R_1^2} \text{ (Tension)...........(5)}$$

Maximum fibre stress is at inside fibre, $S_1 > S_2$.

Error of Computing as a Thin Hollow Cylinder.

When there is external pressure only the difference of intensity of stress on the inside and outside fibres is equal to the intensity of external pressure; for, subtracting (3) from (2),

$$S_1 - S_2 = \frac{2 R_2^2 - R_1^2 - R_2^2}{R_2^2 - R_1^2} P_2 = P_2 \text{ .... (6)}$$

From Equation (6), it follows that the thickness may be approximately computed by the formula for thin hollow cylinders, using for the allowable stress the working stress that would be used for the allowable maximum stress with the formula for thick hollow cylinders diminished by one-half the intensity of the external pressure P_2. The error is not, however, on the safe side. A concrete case is worked out below by the two methods.

Assume conditions as in third line of Table, p. 116, for the Rondout siphon.

P_2 = 519 ft. head of water = 225 lb. per sq. in.
R_1 = 87 in., that is, radius of 14 ft. 6 in. diameter tunnel.
S_1 = 1 500 lb. per sq. in.
T = 17.0 in. as obtained by formula for thick cylinders, Equation (2) above.

By the approximation above described,

$$\left(1\,500 - \frac{225}{2}\right) T = (R_1 + T)\,225.$$

T = 16.85 in.

DISCUSSION.

MR. ROBERT R. CROWELL.—Gentlemen, we have listened to the very interesting paper by Mr. Wiggin and I think there are some other gentlemen here, interested in this matter, who will probably say a few words before the meeting adjourns. We would like to hear from Mr. Ridgway on this subject.

MR. ROBERT RIDGWAY.—The undertaking of the construction of the great pressure tunnels which have been described was probably the boldest step taken by the Board of Water Supply in its work. While the designs follow precedent, they represent a long step in advance of anything of the kind that has gone before. The New Croton Aqueduct, it will be remembered, passes under the Harlem River in a rock pressure tunnel over 300 ft. below tide, and has worked successfully for over 18 years. The unbalanced head to be reckoned with in that tunnel, however, is to be far exceeded in the tunnels described to-night.

The Board was very fortunate in securing the services of Mr. Wiggin and his assistants, who have given such conscientious study to the subject. Under the direction of the Chief Engineer, Mr. J. Waldo Smith, and of Mr. Alfred D. Flinn, the engineer in charge of Headquarters, they have handled the problems in such a broad and thorough way that thus far at least we have met with no unpleasant surprises in the construction, which is now well advanced. Our confidence in the safety and durability of these tunnels, and their ability to do the work they are designed for, increases as the work advances.

The siphon that has naturally attracted the most attention is the one for the Hudson River. This is partly because it is necessary, on account of the great depth of the pre-glacial gorge, to drive the tunnel under this tidal stream at a depth unusual for aqueduct structures. I have always thought, and still believe, that the most difficult one to construct is not the Hudson River siphon, but the tunnel 4½ miles long under the Rondout Valley. This is because the geological structure of the latter valley is so complex, and because of the faulted and folded character of the rock. At least eight formations have to be negotiated, including shales of varying degrees of hardness, limestones of different series, the hardest kind of quartzite and water-bearing sandstones. Compared with this tunnel, the Hudson River problem appears simple. In spite of the conditions mentioned, however, the contractor for the Rondout siphon is over half a year ahead of the progress scheduled in the contract, and is rapidly gaining.

MR. MERRITT H. SMITH.—Mr. President and Gentlemen: I do not know that there is anything that I can add to the very interest-

ing paper which Mr. Wiggin has given us. There is no one connected with the Board of Water Supply who could have done greater justice to the subject than has Mr. Wiggin.

I might say that the only siphon so far under construction in the Southern Aqueduct department is the one at Croton Lake which the author has just described. Both the downtake and the uptake shafts are now under way. The downtake shaft has been excavated to a depth of about 120 ft., and the uptake shaft to a depth of about 180 ft., and about 60 ft. of concrete lining has been placed in the latter shaft.

The plans were so skilfully worked out at Headquarters that all the difficulties to be encountered, no doubt, have been foreseen and carefully provided for.

MR. LAZARUS WHITE.—As has been said regarding the Rondout siphon, we have not met with many surprises. The main thing is to be prepared. We knew we were tackling a difficult thing and we took our time in preparing ourselves and we spent a little money, for which we were criticized, I suppose, but I think it was amply justified. There were about 45 drill borings, the maximum about 600 ft., and we had good authorities exploring around there and they developed that country pretty well, so that the Contractor was forewarned about what he would strike in the way of strata and especially clays, and he prepared himself accordingly, and he has been somewhat surprised to find that at about the points indicated he has struck what we predicted. This is not always the case.

Very good progress has been made. It is a little over a year since the work was started, and yet all the shafts but one are down. One of the shafts is over 700 ft. deep; one, about 600 ft. deep, was put down in a little over 6 months. The tunnel is very long, about 4½ miles, and on a clear day you can hardly see from one end to the other. In a week or so some of the headings are coming together and others will shortly follow, until there will be only one gap at the bad shaft. At that shaft the difficulties were pretty well anticipated. The Contractor has a very good plant there and it is going down fairly well. The shaft has all the difficulties you could ask for. There is all the water you can pump and all the gas you care to breathe. There is a lot of iron pyrite in the rock, which seems to decompose and generate hydrogen sulphide gas, which is very hard on the eyes, and when the gas is at its worst a man can only work a few hours at a time. There is one completed tunnel 3 400 ft. long, which was started less than a year ago. Last month 11 headings were working and averaged 300 ft. apiece. Last week one of the headings made 110 ft., which is at the rate of over 400 ft. a month. So far there has been over two million dollars' worth of work done in a little over a year.

I think Mr. Wiggin has exhausted all the other points and explained them so thoroughly that there is very little I can say, except that so far they seem to have anticipated nearly all the difficulties we have encountered.

MR. WM. W. BRUSH.—It is hardly necessary to repeat what the other gentlemen have already said, that Mr. Wiggin has given us a great deal to think about by his full description of the pressure tunnels for water conduits.

The work with which I am connected is the terminal or City end, and we are now carrying on studies of location and design in the office and making borings to determine geological conditions along proposed tunnel lines. When one considers that the new supply of 500 mil. gal. a day requires something like sixteen 66-in. steel or cast-iron pipes to convey it through The Bronx and into the boroughs of Manhattan, Brooklyn, Queens and Richmond, one can see the difficulties that would have to be met and overcome in finding space to put such a large number of pipes.

Even though the streets in The Bronx and in Manhattan have at present sufficient space within which to install so many large pipes, the presence of these pipes would seriously interfere with, if not prevent, the construction of future subways and other subsurface structures, which must necessarily follow the north-and-south avenues. The installation of, and subsequent repairs to, pipe lines would be a serious inconvenience and possible financial loss to those doing business or residing in the vicinity of such pipe lines. The danger to life and property from possible failure of such large mains should also be given consideration.

The pressure tunnel, which would be driven 200 ft. or more below the surface, would eliminate many of the problems, represent little more than 50% of the construction cost of pipe lines, and give much lower maintenance charges. The possible deferment of the installation of some of the pipe lines would make the actual economy of the tunnel somewhat less than would be indicated by comparison of construction cost. The studies made, both in the office and in the field, indicate that it will be feasible to adopt the pressure tunnel from Hill View to Brooklyn for the City section of the Catskill Aqueduct, and I have no doubt that the problem will be solved as satisfactorily and successfully for the delivery of the supply within City limits, as it has been for the delivery of the supply from the Catskill Mountains to the proposed Hill View Reservoir just north of the City line.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 52.

PRESENTED NOVEMBER 24TH, 1909.

THE NEW YORK STATE BARGE CANAL.

BY FREDERICK SKENE,* M. M. E. N. Y.

WITH DISCUSSION BY

ROBERT R. CROWELL, MAX L. BLUM, WM. G. FORD, GEORGE A. TABER, AND FREDERICK SKENE.

The work of constructing what is known as the Barge Canal is carried on under Chapter No. 147 of the Laws of 1903, commonly known as the Barge Canal Law. Comparatively few people in the State really appreciate or, in fact, know much about this great work, for which the State will expend more than $101 000 000.

For several years prior to 1903 shipping interests of the State were noticing that there was an appreciable diminution of trade to and from the Port of New York. Not only New York City but the entire State realized that it would be necessary to take immediate steps to not only retain its commerce but to be able in the future to be in a position to compete successfully with other States and with Canada. It was decided that the only way this could be done was by an enlargement of the Erie Canal. The Legislature appropriated the sum of $9 000 000 to do this work. The improvement, however, did not prove a success for several reasons. Among others, a dual responsibility was created which permitted two entirely distinct organizations to take charge of the work, which was the means of causing endless and unnecessary controversy and no harmony of action. Also the work of improvement was started, contracts awarded, etc., before definite and com

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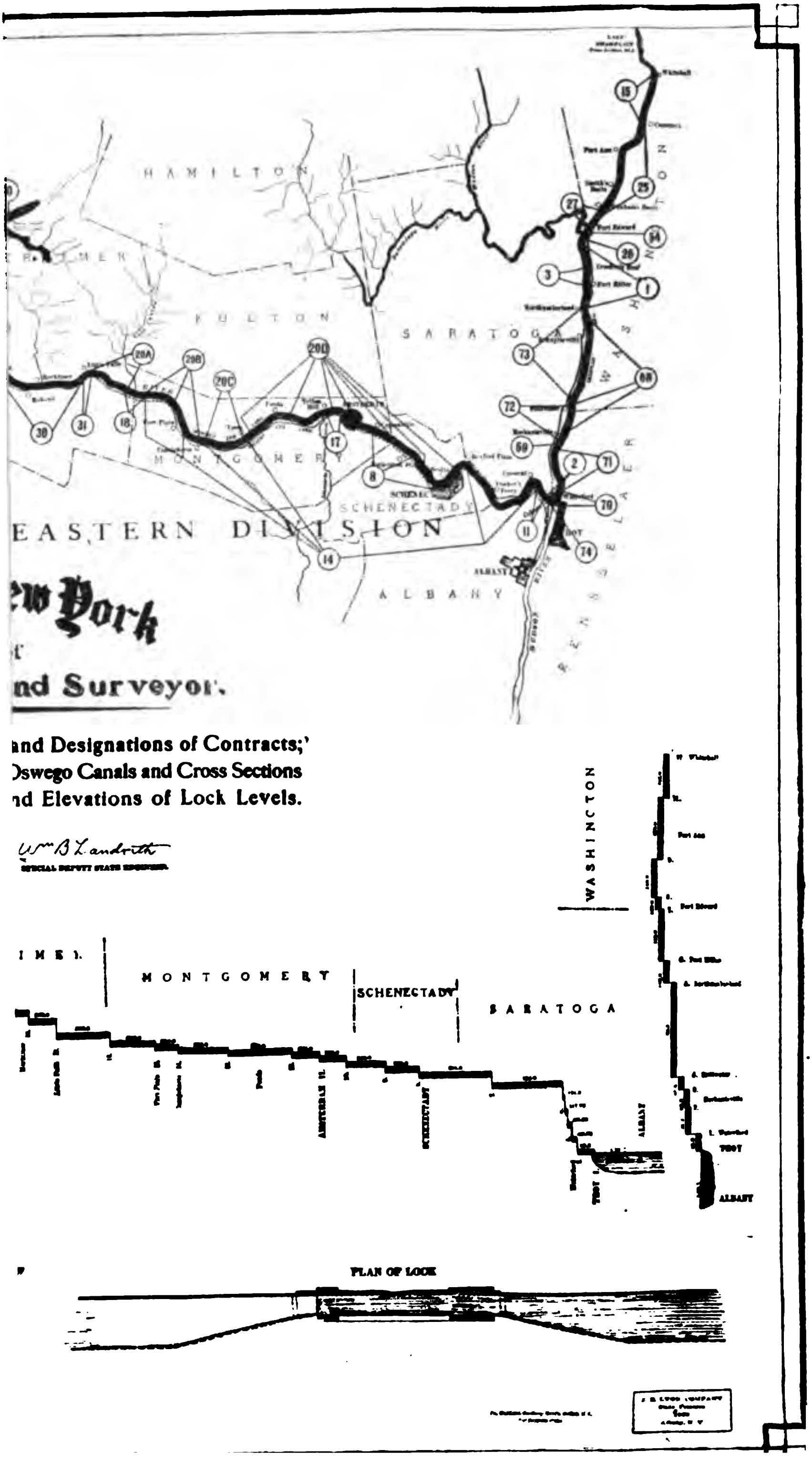
HAMILTON
FULTON
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MONTGOMERY
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ALBANY
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ew York
nd Surveyor.
and Designations of Contracts;
)swego Canals and Cross Sections
nd Elevations of Lock Levels.
Wm B Landreth
SPECIAL DEPUTY STATE ENGINEER.
MONTGOMERY
SCHENECTADY
SARATOGA
WASHINGTON
AMSTERDAM
SCHENECTADY
ALBANY
TROY
ALBANY
PLAN OF LOCK

plete plans had been decided upon. After a few contracts had been awarded it was found that the expense of this dual condition, the necessary changes in contracts awarded and the continual disagreements had entirely eaten up the appropriation and the State was in a condition of having a number of contracts awarded which there was not money enough to complete, and that they were liable to large damages for prospective profits, plants, etc., by the various contractors.

This resulted in a complete stoppage of the work and rather dampened the spirits of those interested in the enlargement of the waterways of the State, but almost immediately it was taken up with renewed vigor, and only a State as financially strong as New York could possibly have again taken up the question under the conditions then existing. A commission was appointed by the Governor to look into the entire matter, and as a result an appropriation was made and the State Engineer authorized to proceed with the necessary surveys, preliminary estimates, etc. As a result the State Engineer reported in favor of a canal 12 ft. in depth, with a carrying capacity of one thousand tons, at an estimated cost of $101 000 000, and it was upon this report that Chapter No. 147 of the Laws of 1903, known as the Barge Canal Act, was based. This directed the State Engineer to make all surveys, estimates, plans and specifications, and to have the direct supervision of the construction work. The Superintendent of Public Works was directed to advertise and award contracts and make payments on the same upon the certificate of the State Engineer. This law also created what is known as the Advisory Board of Consulting Engineers to act in an advisory capacity to the Governor, the Superintendent of Public Works and the State Engineer and Surveyor. Another board, known as the Canal Board, was created by the law of 1903, consisting of the Lieutenant Governor, the Secretary of State, the State Comptroller, the Attorney-General, the State Treasurer, the Superintendent of Public Works, and the State Engineer. This board has the final voice or veto power on all matters pertaining to the work. Its approval is necessary of all plans, specifications, contracts and alterations, and also upon all contracts entered into for the appropriation and buying of land to be used for canal purposes.

The plans as prepared by the State Engineer for 1902-3, upon which the law was based and also upon which are based to a great extent the present plans, do not contemplate so much an enlargement of the old Erie Canal as an entirely new and distinct Barge Canal. The old Erie Canal, and the canals built at that period and prior, were generally constructed more upon side hills and away from the rivers, lakes and lowlands, whereas the route of the new canal follows as much as possible the trend of rivers, streams and lakes, canalizing and utilizing them in every possible way.

The length of the present project is 442 miles, and includes the canal from the Hudson River west to the Niagara River, from Syracuse north to Oswego, and from Waterford, just north of Albany, northward to Lake Champlain. It is contemplated to build 61 locks, 25 fixed dams, 15 movable dams, 18 guard-gates, a steel arched viaduct 250 ft. in length, 3 storage reservoirs of immense capacity, over 200 bridges and numerous other minor structures. Almost all the preliminary work has now been completed. In an undertaking of this character it can readily be seen that great care must be taken and the most extended investigation of all existing and prospective conditions made.

The natural advantages in the topography of the State were at once recognized. From the head of navigation of the Hudson River a chain of rivers and creeks with comparatively low summit elevations extends west to connect with the Niagara River and Lake Erie, north from the central portion of the State to connect with Lake Ontario and also northerly at the head of navigation of the Hudson to and connecting with Lake Champlain.

During the period from 1817 to 1830 the canal boats were 61 ft. long by 7 ft. beam, with a capacity of 30 tons or 1 000 bushels of wheat. During the period from 1830 to 1850 on the original canal the sizes increased to 75 ft. long by 12 ft. beam, with a capacity of 75 tons or 2 500 bushels of wheat. From then on, from time to time, the sizes of the boats and their carrying capacity increased. According to the present plan for the Barge Canal, boats 150 ft. long by 25 ft. beam and 10 ft. draft, with a capacity of 1 000 tons or 33 333 bushels of wheat can very readily be accommodated.

The original canal, built in 1817, had a bottom width of only 26 ft., a top width of 40 ft., a depth of 4 ft. and an area of 132 sq. ft.

FIG. 1.—LOCK NO. 12, AT TRIBE'S HILL.

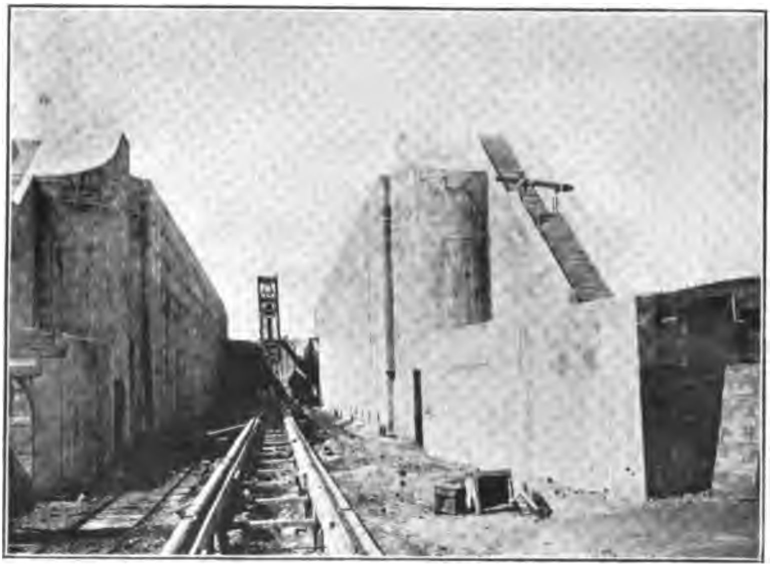


FIG. 2.—LOCK NO. 5, AT WATERFORD.

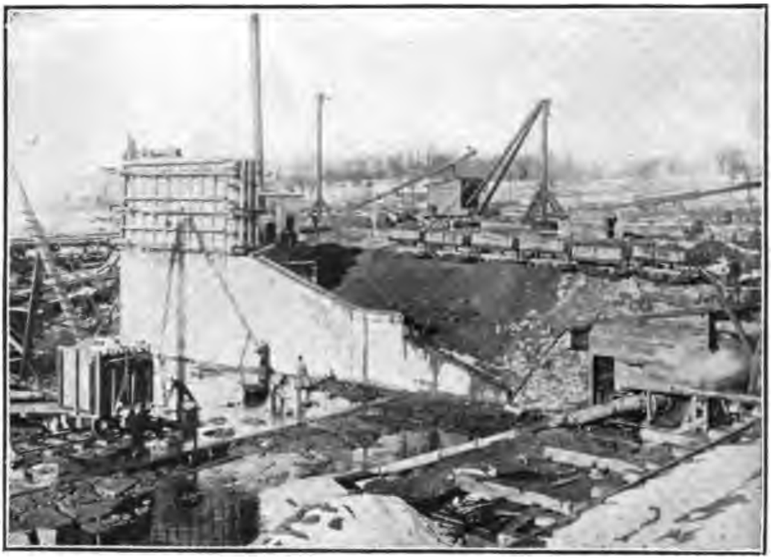


FIG. 1.—FOUNDATION FOR DAM ABUTMENTS AT PALATINE BRIDGE.

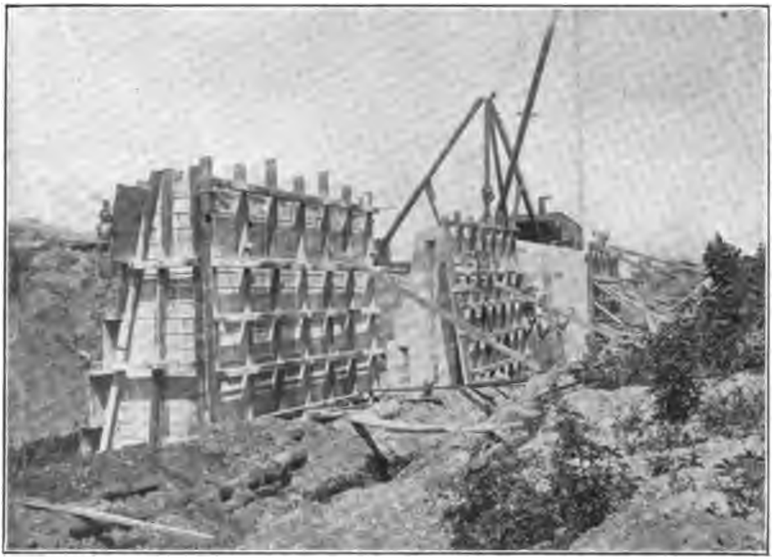


FIG. 2.—GUIDE WALL AT FORT PLAIN.

The enlargement of 1862 gave a bottom width of 52 ft., a top width of 70 ft., a depth of 7 ft., and an area of 427 sq. ft. The suggested improvements were $9 000 000 and proposed a bottom width of 49 ft., a top width of 73 ft., a depth of 9 ft., and an area of 549 sq. ft. The present contemplated land section will be 75 ft. on the bottom and an average of 122 ft. at the top, 12 ft. in depth and will have an area of 1 182 sq. ft. As shown on Plate 51 the earth section of the canal, as it will be in going overland where rivers and streams are not followed, has a bottom width of 75 ft., a depth of 12 ft. and a top width varying with the character of the soil encountered. The river sections have a depth of 12 ft. and a width of 200 ft. The rock or retaining-wall sections which are used in going through rock, cities or important villages is 12 ft. in depth with a bottom width of 94 ft. It will be seen that what is known as the Barge Canal, is really three canals; one running from Waterford to Tonawanda and the Niagara River, another from Waterford to Whitehall, connecting the Hudson River with Lake Champlain, and another from Three River Point to Oswego, connecting the central part of the State with Lake Ontario. The bottom portion of the Plate 51 shows a profile of the canal, giving the elevations of the various levels and lines of the locks.

In the East and West Canal we have a summit level at Rome, where it is fed by the Mohawk River and West Canada Creek. We have another summit level in the extreme western end fed by the Niagara River, the water running east to Three River Point and thence down to Lake Ontario at Oswego. In the Champlain Canal the summit level is at Glens Falls and is fed by the Hudson River, the water running south by means of canalization to Waterford, and north along what is known as Wood Creek to Whitehall and Lake Champlain. On this plate is also shown a plan of one of the locks. These locks, according to the original Act, were to have been only 28 ft. wide, but afterward, by legislative act, were widened to 45 ft. They are 310 ft. long with 12 ft. of water over the miter sills. It can thus readily be seen that the 1 000 tons capacity canal as originally planned, is, by the fact of the widening of the locks, almost double that capacity.

The main route of the canal as adopted is as follows: Leaving the Hudson River at Waterford it rises by a series of five locks, each having a lift of 34 ft., to the Mohawk River west of Cohoes

FIG. 1.—SECTION OF FINISHED CANAL NORTH OF PAYNE'S BRIDGE.

FIG. 2.—SECTION OF FINISHED CANAL NORTH OF PAYNE'S BRIDGE, SHOWING WASH WALL.

DISCUSSION.

MR. ROBERT R. CROWELL.—We have listened to the very interesting paper by Mr. Skene, and if there are any questions to be asked I know he will be very much pleased to answer them.

A MEMBER.—What is the usual lift of each lock?

MR. SKENE.—They average between 25 and 30 ft.; that is, the canal running east and west and north to Oswego. On the canal running north from Waterford to Whitehall and on the canalizing of the Hudson River to Fort Edward, the lift will be only 10 ft. on all the locks.

MR. MAX L. BLUM.—There are two questions I would like to ask, Mr. President. Back in 1896, if I remember rightly, there was a Deep Waterway Commission appointed for the purpose of drawing up plans so that ships could go from the Great Lakes to the ocean. Has that plan been done away with?

MR. SKENE.—Oh, yes.

MR. BLUM.—Another thing that came to my mind was this: When Gov. Flower went out of office he became interested in electric operations for canal boats? Has anything ever been done with that?

MR. SKENE.—No, not to any extent. There have been several ideas tried but none of them had any success at all, although there is a movement on foot to develop enough power at the State dams to be utilized, if they wish it, in the operation of the boats, but nothing definite has been decided about it at all.

A MEMBER.—I would ask Mr. Skene how stagnation of the water is prevented in the canal?

MR. SKENE.—The water is almost continually moving. In the rivers the water is continually on the move and in the canal section it is continually moving on account of the emptying and filling of the locks. The water is fed at the summit level and is gradually dropping down as the lock is emptied and filled again, until it gets to the Hudson River, so that the water is kept continually moving.

The Mohawk River and West Canada Creek supply the water of the summit level. The two dams of which I spoke are at Hinckley and Delta, and the water is fed down as it is needed to the canal and is taken either west or east, as required. During the Winter, when the canal season is closed, the movable dams are open, so that the water in the rivers has a clear flow.

A MEMBER.—Will the power you spoke of as being developed at the dams be used for their operation?

MR. SKENE.—Oh, yes. The locks are to be operated by electric

power produced at the dam sites. This power will also be used for lighting and other purposes.

There are nine dams in the Hudson River from Glens Falls to Waterford. Then it locks down. Part of the water from the Hudson River is used to lock down to Lake Champlain, although Wood Creek is utilized as a feeder.

Mr. Wm. G. Ford.—Has there been any approximate estimate of the traffic of the canal between the Lakes and New York City?

Mr. Skene.—Not that I know of.

Mr. Ford.—Has there been any data had, with any degree of approximation, which would show the effect of the freight rates to New York from the Lakes?

Mr. Skene.—No. There has been data gotten up by various commercial bodies. The N. Y. Board of Trade and Transportation had some data along that line, but nothing definite.

Mr. Ford.—Has there been anything done in the probable quantities of material that can be handled?

Mr. Skene.—The amount of carrying, you mean?

Mr. Ford.—Yes, sir.

Mr. Skene.—The market from Buffalo coming East?

Mr. Ford.—Yes. To what extent it would affect New York as regards the getting of the heavy traffic and such things as that,—heavy materials.

Mr. Skene.—It is hoped to practically control it. Of course, the canal is going to have Canada and her canals as a competitor—and Canada is spending millions to-day and building a larger and deeper canal than we are doing. She is building canals which are capable of transporting the Lake vessels, whereas in our canal, the load will have to be trans-shipped at Buffalo.

Mr. Ford.—Has there been any fairly good guess as to the time of completion?

Mr. Skene.—From five to six years.

Mr. Ford.—From now?

Mr. Skene.—Yes. The plans are practically all completed now, and they ought to be under contract by the middle of next year for the entire length, and none of the contracts will take more than three or three and one-half years, so that five years or six years at the outside ought to complete it.

Mr. Ford.—Has the increased size of the locks increased the estimated tonnage of 20 millions capacity?

Mr. Skene.—Well, yes.

Mr. Ford.—Has the total estimate, or estimate of the total quantity of capacity gone up above 20 million yet?

Mr. Skene.—Oh, yes.

Mr. Ford.—What is that now?

MR. SKENE.—I don't know offhand, but it is quite a little over that, I am quite sure. The increase of the locks has not increased the cost over the $101 000 000. That is, up to the present time, taking the contracts which have been awarded as a criterion, the cost of construction is less than the original estimate, so that the increased cost of widening the locks and strengthening them will not overcome that difference, so that even with the increased width and increased cost of lock, they will still be within the $101 000 000.

MR. FORD.—Will you tell us something about your idea of the terminals, especially the New York terminals?

MR. SKENE.—The terminal question is a very important one and should be taken up immediately. Manhattan Island is practically all taken up; that is, the facilities cannot be increased on Manhattan Island, either on the North River or the East River, and in order to maintain the traffic in this State I think that something should be done on either The Bronx shore or the Long Island shore, so that Jersey will not get the benefit of the traffic. In the spending of the $101 000 000 we ought to do something immediately, I think, to get the traffic facilities ready when the trade begins to come. The first fellow in the field always has the best chance, and we ought to be ready by the time the trade comes to take it on our shore instead of letting the good of the whole project go to another State.

A MEMBER.—I should like to ask Mr. Skene if the proposed location of the new locks at Lockport is the same as those of the present Erie?

MR. SKENE.—Just the same, only there will be a much larger lift. The new locks at Lockport will have a lift of 55 ft.

MR. CROWELL.—Could you tell us how long it would take to fill these locks, i. e., to lock a boat up?

MR. SKENE.—About two or two and one-half minutes. They have plenty of large supply pipes.

A MEMBER.—What per cent. of the Erie Canal will be utilized in the Barge Canal?

MR. SKENE.—I should say about 10 per cent.

A MEMBER.—If they use power, how will the bank be protected from the wash?

MR. SKENE.—A wash wall is built almost the entire length of the canal. This wash wall is of heavy rock, and is hand placed.

MR. GEORGE A. TABER.—As I understand it, the canal is only fed on the high levels. The evaporation from such a large water surface as there is in a canal of this size and length must be great, and the seepage, it seems to me, would amount to considerable, and I would like to ask the author if the amount of water let down

by the passing of the boats through the locks will make up for this deficiency, or whether it is intended to take advantage of any other sources of supply to provide for this?

MR. SKENE.—We take advantage of every stream we come to that we can utilize. By means of a guard gate we let the water in.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 53.

PRESENTED DECEMBER 22D, 1909.

THE REDUCTION OF THE WATER TABLE AND ITS EFFECT ON FOUNDATIONS IN NEW YORK CITY.

BY FRANCIS L. PRUYN.*

WITH DISCUSSION BY
ROBERT R. CROWELL, RUDOLPH P. MILLER AND FRANCIS L. PRUYN.

MR. PRESIDENT AND MEMBERS OF THE MUNICIPAL ENGINEERS:

It gives me much pleasure to address you to-night, for while not a member of your society I cannot help but feel myself among friends. I even might lay claim to being a Municipal Engineer, for I have been an engineer in the employ of the city and have done much of my engineering work within the city's limits.

The question of sub-surface conditions here in New York is always an interesting one. The unexpected is always happening, one must keep constantly on the alert to guard against unforeseen conditions, and one is always developing some new problem to be met and overcome.

Bed rock has been located under all parts of Manhattan Island. Above Fifty-ninth Street, the outcrops are frequent and prominent, below that street the rock is pretty much below the surface. Such hollows as occurred below tide water have been filled in by the great rivers surrounding the island, with the result that much fine material is found at varying depths below the surface as is experienced in the delta of all large rivers. The underlying rock is extremely uneven in its formation. I know of one instance where it dropped 50 ft.

* Vice-President of the Underpinning Co. and Consulting Engineer, 290 Broadway New York City.

within the area of a 100-ft. building lot. The overlying material is of widely differing character, its nature changes with unexpected rapidity so that information gained in one locality is not reliable for adjoining sections. There is one downtown section where, within the distance of a city block of 250 ft., the nature of the ground changes from a good sharp sand practically at the surface, to bog and soft mud, with firm footing 80 ft. below the curb.

The old Viele topographical map is probably the best existing record of the original surface conditions existing on Manhattan Island. The location of the old water-courses, ponds, swamps, etc., are accurately recorded. The old stream through Canal Street is there shown, which I believe is the only water-course still remaining open in the city, and the Collect Pond on Centre Street, which has recently given so much trouble in the building of the Subway through that street. The Criminal Courts Building, which has gained considerable newspaper notoriety during the past month, is situated directly on this pond. There was another old pond at about the site of the Park Avenue Hotel. The streams leading to and from it were met during the construction of the Pennsylvania Crosstown tunnels and caused considerable trouble. I recall quite vividly the day a drill hole went through the roof of the Thirty-second Street tunnel, near Fourth Avenue, and a large stream of water flowed in under considerable pressure. It was thought that the whole pond was coming in, but, in a few hours, the flow ceased entirely and no further difficulty from water was encountered at that point.

These old water-courses were fed by springs, and when the surface water is diverted by pavements and roofs into sewers, their sources of supply are cut off, and beyond a certain amount of saturation of the soil no further flow takes place. There was another stream at Fifty-ninth Street and Sixth Avenue, near the location of the New York Athletic Club, that caused considerable trouble during the construction of that building. This stream is probably still fed from the open spaces found in Central Park and is therefore still active. As a rule the water table in New York City in localities distant from the river front is a very unstable quantity. It is influenced by a great many local conditions which cannot be foreseen, and is therefore a quantity not to be counted upon in the design of foundations.

PLATE 58.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
PRUYN ON REDUCTION OF THE
WATER TABLE IN NEW YORK CITY.

FIG. 1.

FIG. 2.

FRONT AND REAR VIEWS OF HANAN & SON'S BUILDING, CENTER AND WHITE STREETS, SHOWING WEDGESHAPED CREVICE DUE TO SETTLEMENT REFILLED WITH BRICK WORK.

There are many instances where wooden piles have been used in the foundations of buildings where the piles were cut off well below the then existing water table. Deeper excavations of adjoining buildings or adjacent tunnels or subways have considerably lowered the water level with the result that the heads of the piles have decayed and the buildings settled.

It is a well-known fact that the pile foundation under two large downtown office buildings are now well above water level. In both cases subways have lowered the water table since the buildings were erected. Both these foundations are now under constant inspection and it is only a question of time when their disintegration will proceed far enough to warrant new foundations.

During the construction of the subway on Centre Street some remarkable conditions developed in the adjacent buildings. The subway passed through the site of the old Collect Pond, and more or less water was encountered which had to be removed by pumps. The sumps were located about 25 ft. below the curb, and the pumping operation extended over a period of 10 or 12 months. The bottom of the old pond was struck anywhere from 10 to 20 ft. below the curb, and consisted of peat, decayed vegetable matter, muck, etc. Below this bottom soft material extends to a depth of from 75 to 100 ft. below the curb. The old pond was filled in many years ago and the buildings were erected on the filled material. Between Worth and Canal Streets every building has settled anywhere from 2 to 8 in. Just how much of this settlement is due to the lowering of the water table has not been determined, but it certainly had considerable influence in disturbing the condition of equilibrium of the buildings at a time when a deep excavation was being made adjacent to them and therefore at a time to exaggerate such movement.

Several of the buildings were so far away from the excavation as to be well beyond its influence except on the lowered water level theory. At one of these it was found the water table had been lowered about four feet at a distance of 200 ft. from the subway excavation.

Considerable settlement took place in the sidewalks and streets as well as the houses, which showed a settlement of from 4 to 5 in. The curb and sidewalk opened up cracks to a distance of 75 ft. back from the line of excavation and showed a total movement towards the subway of about three inches.

Plate 58 shows the large factory building situated directly opposite the Criminal Courts Building—a 7-story structure, fronting 75 ft. on Centre Street and 100 ft. on White Street. The foundations rest on piles which are placed in great numbers under the piers and under the inverted brick arches between the piers. Levels taken on the building for a year previous to the subway construction show no appreciable settlement; those taken during the year when work was in progress and pumping was continuous, showed a settlement of three to six inches.

The photograph shows quite clearly the brick V which has been placed at the east building line to fill the opening between a new building, which was erected recently and has vertical walls, and the factory building. This brick V had to be removed and replaced six months after it was put in on account of the continued movement of the factory building. These views were taken in December, 1909, and show by the 1-in. crack extending the full length of the building that the movement still continues. The subway sidewalls at this point have been in place about six months, although pumping still continues.

Plate 59, Fig. 1, shows a building at the corner of Centre and Franklin Streets, which at the time this photograph was taken had settled considerably and had been shored up preparatory to rebuilding a portion of the lower floor. This building was underpinned by the Subway contractors on the Centre Street face, and when disturbance of the ground took place a building directly in the rear settled away from Centre Street, thus opening up a 2-in. crack between the corner building and the one directly to the east. This is the only instance that I know of where a building settled in a direction away from the subway excavation. The pumping had been going on in this neighborhood for six or eight months before the settlement took place.

On Leonard Street, about 100 ft. away from the Centre Street building line, is a heavy 8-story loft building heavily loaded, in which the estimated weight on the sidewalls was 18 tons per running foot of wall. Considerable settlement had taken place, and the top of the building had moved about two inches to the west, or towards the subway excavation. The wall was supported on piles, and preliminary investigation showed that the top of some of them had

FIG. 1.—BUILDING ON CORNER OF CENTER AND FRANKLIN STS.

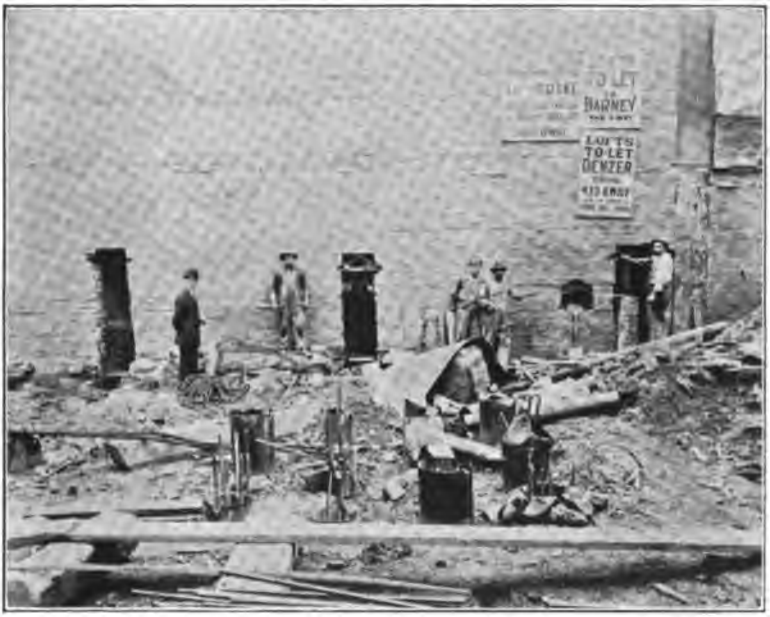
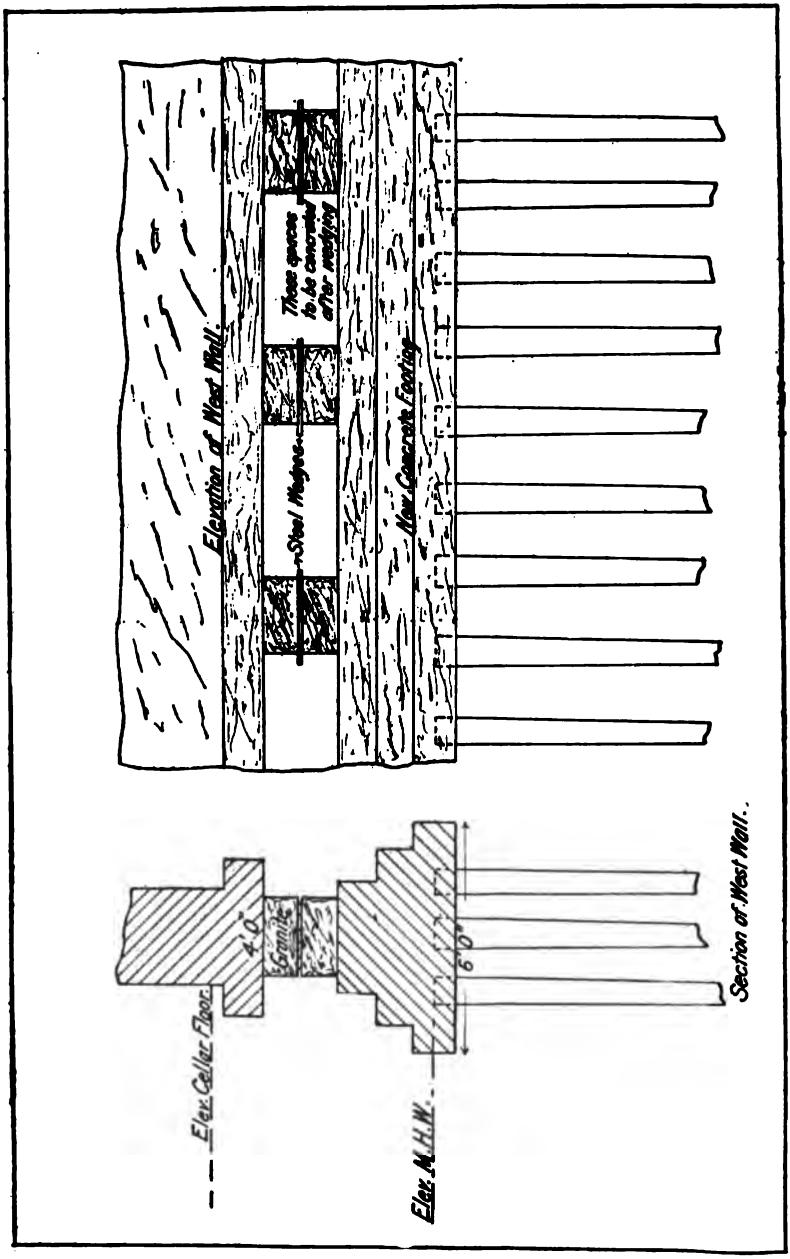


FIG. 2.—BUILDING ON FRANKLIN ST., WEST OF WEST BROADWAY.

PLATE 60.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
PRUYN ON REDUCTION OF THE
WATER TABLE IN NEW YORK CITY.



UNDERPINNING AND NEW FOUNDATION FOOTINGS FOR NO. 149 LEONARD ST.

rotted away. It was at first supposed that all the piles were affected in this manner, and that settlement of the building had been caused by loss of bearing power through their decay, but further developments showed that a comparatively small number of piles had rotted, and that therefore the settlement was attributable to other causes.

The tops of the piles were at an elevation of about 4 ft. above mean high water level, and from information obtained it was learned that these piles had been above the water table at the time the building was built, or about 18 years ago. The water table has been lowered in this section about three feet since this building was constructed and at the time this photograph was taken pumping in the subway excavation had lowered it about three feet further.

The owner of the building determined to underpin it, and the method shown on Plate 60 was employed. The piles were cut off at about 1 ft. below mean high water, a spread concrete footing placed upon them, upon which granite wedging blocks were placed, and the weight of the building transferred to the new foundation by steel wedges. The wall was not needled in doing this. Excavation was carried down in 6 ft. pockets one at a time and the wall picked up on wedging blocks before the adjoining section was excavated. After the wall had been wedged up, the spaces between the wedging blocks were filled with concrete and the excavation backfilled. At the angle of the return wall in the rear of the building and on a pier adjoining it and supporting a heavy concentrated load, it was necessary to needle the wall before the underpinning process began. Four 24-in. 100-lb. I-beams were placed through the walls, which was picked up by screw jacks placed upon suitable blocking. After the wall had been picked up the operation of underpinning was the same as above described.

At two points it was thought advisable to put piles under the walls, and, as it was impossible to use a pile-driver in the cellar of the building, these were jacked down in place directly under the wall. Four-foot lengths of 9-in. wrought-iron pipe were used, the first sections having a pointed shoe, and each following section having a sleeve fitting tightly inside the pipe to connect it with the preceding section. These piles were jacked down to a depth of about

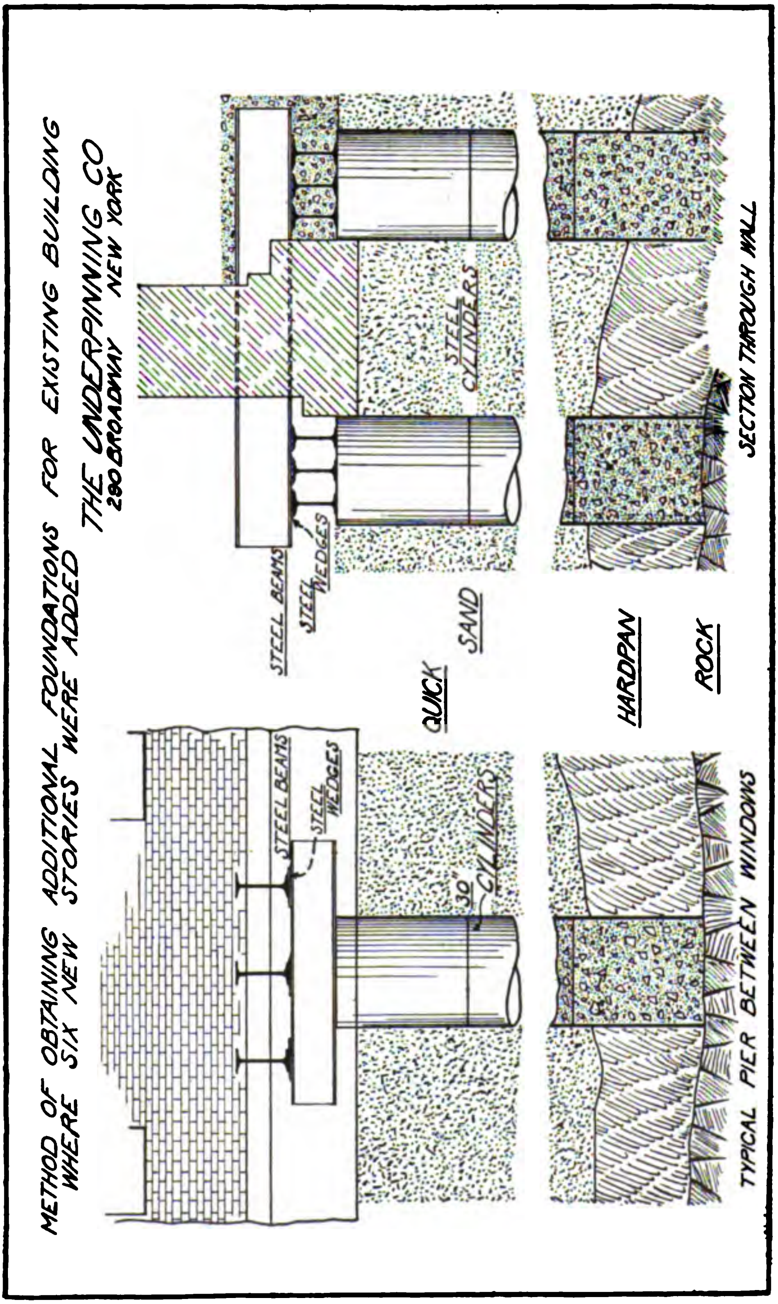
50 ft. below the wall footings, where they brought up on a firm material. The gage reading on the hydraulic jack showed a resistance of 70 tons. After this reaction was obtained, the jack was removed and the piles were filled with concrete. They were then concreted in, the same as the wooden piles and the load taken upon them through wedging blocks and steel wedges.

Plate 59, Fig. 2, shows the side wall of a building on Franklin Street directly west of West Broadway, and while the conditions here met had nothing to do with the location of the water table they are, at the same time, interesting as indicating the unexpected conditions to be met with in foundation work in New York City. The wall here shown was supposed to have been on piles, but after the excavation was opened up no piles were found, the wall resting on bog and soft material which extended down to a considerable depth.

The new building was to rest on concrete piles, and as soon as pile-driving began, it so shook the adjoining wall that serious settlement was threatened. It was then decided to underpin the wall by the method shown, which consisted in jacking down sectional pipe in recesses cut in the wall, until a reaction of 60 or 70 tons was obtained, as indicated by the gage attached to the hydraulic jack. The material directly below the mud was gravel, containing small boulders, and some difficulty was experienced in penetrating this material to reach a firm bearing. The pipe was sunk to a depth of about twenty-three feet below the footings, washed out by means of a water jet and then concreted. After the concrete had set, the jack was placed on the concrete pile, and it was forced down until the required reaction was obtained. The piles would start with a reaction of about twenty or thirty tons, and would bring up in about twelves inches to the required reaction of seventy tons. After this reaction had been obtained, granite wedging blocks and steel wedges were placed in the recesses directly over the pipe, and the weight of the wall transferred to the piles. Sixteen piles in all were sunk under this wall. The work was done in about six weeks, and was carried on at the same time that the concrete piles were being driven for the foundation of the new building, so that no delay occurred in spite of the unforeseen conditions encountered.

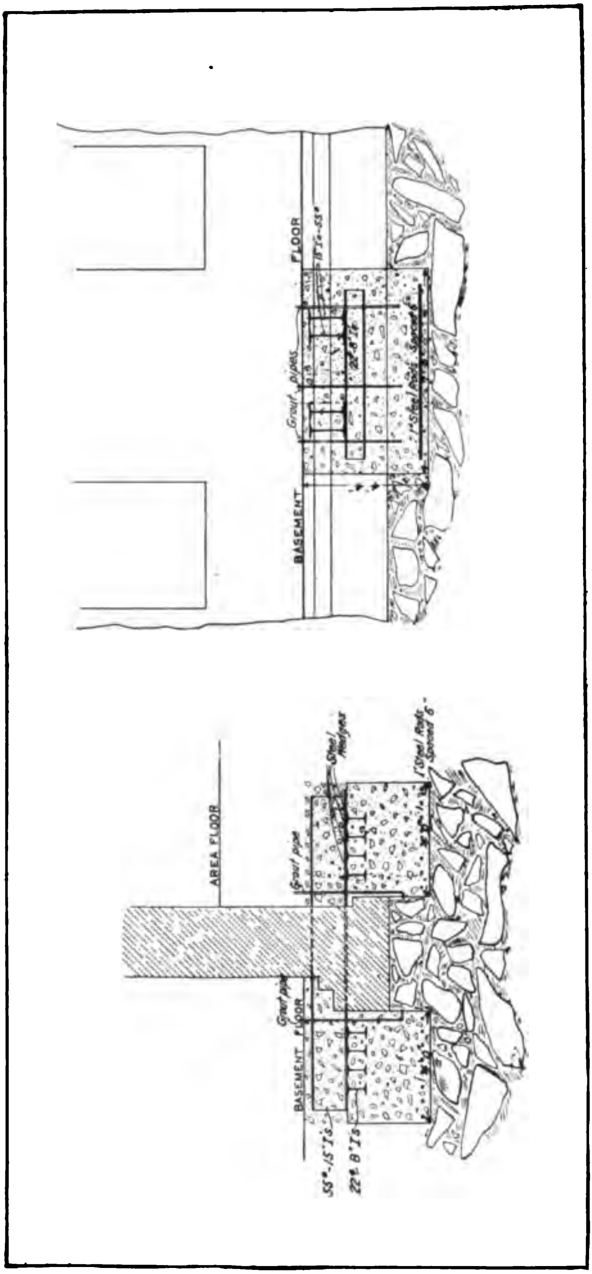
Another very interesting and unexpected condition was met

PLATE 61.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
PRUYN ON REDUCTION OF THE
WATER TABLE IN NEW YORK CITY.



Proposed Plan for Underpinning Walls of Mt. Sinai Hospital.

PLATE 62.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK
PRUYN ON REDUCTION OF THE
WATER TABLE IN NEW YORK CITY.



Plan Adopted for Strengthening Walls of Mt. Sinai Hospital.

with at The Mount Sinai Hospital, at One Hundredth Street and Madison Avenue. It had been determined to add three stories to the existing building, and the writer was called upon to submit a plan to strengthen the existing foundations. The borings showed ordinary fill for a distance of 20 ft. below the curb, and it was said that rock was located at that point. On the strength of that statement a design for the new foundations was made consisting of two 30-in. cylinders, one outside and one inside of each pier in the outer walls of the building. It was planned to jack these cylinders down to rock, fill them with concrete and transfer the load of the piers to the cylinders by means of I-beams run through the wall and resting on top of the piers, as shown on Plate 61.

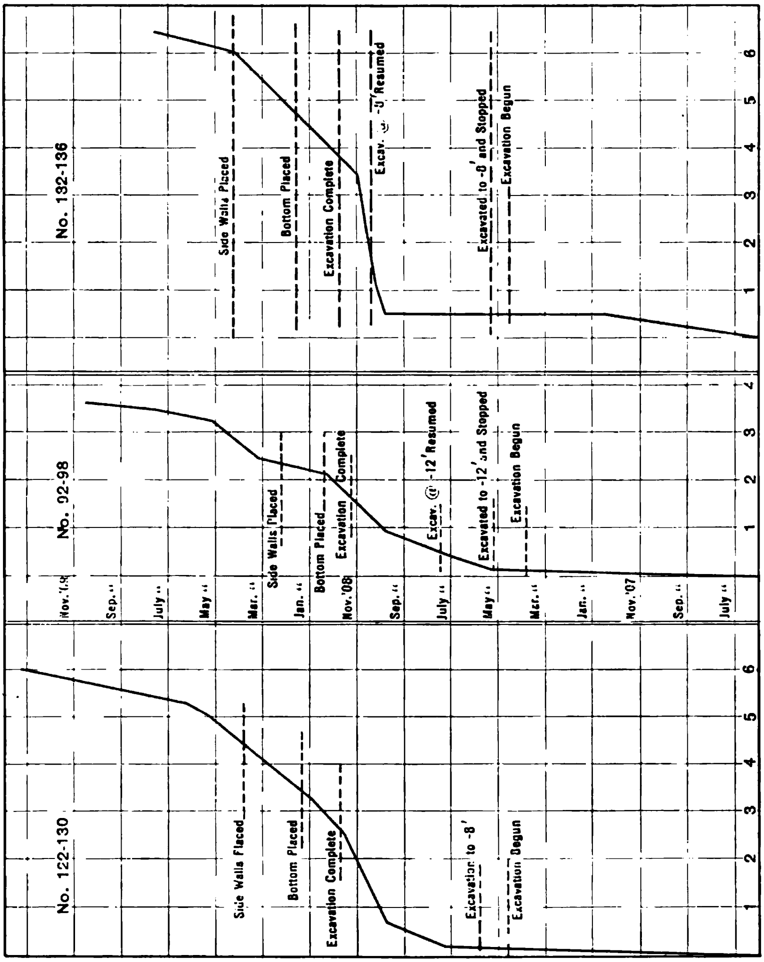
In sinking the first two cylinders it was found that the foundations of the buildings rested on large, loose, rip-rap fill, composed of stone varying in size from 1 ft. to 8 ft. in length, and piled loosely one upon another, without any material to fill in the voids between the stones. As the weight of the existing building rested on this loose fill, and as the 30-in. cylinders were being jacked down within 12 in. of the walls, a very dangerous condition was developed. One cylinder was put down, however, to a distance of about thirty feet below the curb, where quicksand was encountered. The whole plan of sinking cylinders was then immediately abandoned, the cylinder was filled up with concrete and a new plan of underpinning the building devised. Since quicksand existed under the rip-rap fill it was determined to keep as far above it as possible, and the method adopted was in the nature of spread footings on each side of each pier. These spread footings were carried down about 12 in. below the existing footings of the building. An excavation 6 ft. long by 4 ft. wide was made. Steel rods were placed in the bottom to distribute the superimposed load, and the excavation was filled with concrete (see Plate 62). Short sections of wrought-iron pipe were placed in the concrete, through which grout was poured after the concrete in the new footings had set. Holes were then cut through the piers and four 15-in. I-beams inserted through the walls. The I-beams rested on the new footings, and the load was transferred to them by grillages placed in the concrete, upon which steel wedges were driven. The wedging was done from the

outside and inside of each pier simultaneously and without any particular difficulty the entire load of the pier was transferred to the new footings.

A remarkable instance of the lowering of the water level away from a pile foundation, because of tunnel construction, occurred at the old Cambridge Hotel Building on Thirty-third Street, directly opposite the Waldorf Hotel. The Thirty-third Street wall of this building was supported on wooden piles. Settlement took place in the building during the construction of the Thirty-third Street crosstown tunnels, which went directly in front of the building, and the owner decided to underpin the wall. The roof of the tunnel at this point was in rock, and of course the pile supporting the north wall of the building rested on the rock. When the contract was let for the underpinning, the contractor expected to encounter water and to sink the cylinders under the wall by pneumatic process. When the work came to be done, however, no water was found, the cylinders went down dry, and the underpinning work was therefore a very simple matter. It showed, however, that the water table had been lowered on account of the tunnel construction about 24 ft.

Plate 63 shows settlement curves in three buildings along Centre Street. The ordinates are the dates at which the levels were taken and the abscissas are the settlement in the building at those dates in tenths of a foot. The curves start at the date excavation commenced in front of the building, and the depth of the excavation and the date when excavation was completed are shown on the curves. They show very distinctly the increased settlement which took place as soon as the excavation extended below the footings of the buildings, and how it gradually slowed up after the excavation was completed and the sidewalls were in place.

PLATE 63.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
PRUYN ON REDUCTION OF THE
WATER TABLE IN NEW YORK CITY.



CURVES SHOWING PROGRESSIVE SETTLEMENT DURING CONSTRUCTION IN TENTHS OF A FOOT.

DISCUSSION

Mr. Robert R. Crowell.—We have listened with a great deal of interest to the paper by Mr. Pruyn, and if any member desires to discuss this subject we will be glad to hear him.

I understand Mr. Rudolph Miller is here and desires to make a few remarks on this matter.

Mr. Rudolph P. Miller.—I did not expect to talk upon this particular subject. I haven't any accurate knowledge in the matter of the reduction of the water table, but I have had a little experience with work similar to that Mr. Pruyn has described, in connection with the subway construction, notably in the case of the Criminal Courts Building. It might be interesting to the members to have a little history of that building.

It was built about 1890 or 1891, and from the observations made in the course of the last two years, the conclusion was reached that it had started to settle soon after it was constructed. The building being placed on piles, one of the first things that suggested itself in the investigation was whether the piles possibly had been unevenly loaded. The best information available was obtained regarding the piling plan, and from it we learned that the settlement in the pile foundation was not proportional to the loads on the piles. The loads varied very greatly, from 4 tons to about 17 tons per pile, and yet there was no relation whatever between the settlement of the piles and the loads on them. It was, of course, suspected that possibly the piles had rotted, due to the reduction of the water table. The piles which had been exposed were not rotted, and more recently, after the report had been made, further investigation showed that the piles that were then exposed were also in good condition. Some of them showed slight indications of decay, but it was all in the sap layers of the timber. I do not believe there is much danger in the City of New York of the settlement of buildings by reason of rotting piles. Although there may be a reduction in the water table and some of the piles may be above the water line, I think the amount of moisture that is in the soil surrounding the piles will preserve them, and if there is any rotting it will be only in such an extended period of time that very little serious damage can result. I have in mind a building where the piles were exposed at least ten years ago, when ground was excavated on the adjoining premises for an extension to the building. In that case the water table had been lowered, but the piles were in good condition; nothing was done to surround them or encase them further; the

building that is resting on those piles to-day is still standing without signs of settlement, and it is a high and heavy building.

Where settlement of pile foundations has occurred, it is due more to the nature of the subsoil than it is to rotting of piles or to the lowering of the water table. In the case of the Criminal Courts Building, for instance, we know that one end of that building rests over the old Collect Pond. The westerly end of the building rests on a more firm material. When the first subway was built, in what is now Lafayette Street (formerly Elm) there was considerable movement in the Criminal Courts Building, but the settlement did not take place along the subway construction; it took place at the other end of the building, the end away from the subway construction. Before the subway was built in Centre Street, the easterly end of the building was considerably lower than the westerly end. The northeast corner was 4 in. lower than the northwest corner. That was before the subway excavation had started on Centre Street. During the subway construction further settlement took place, and the settlement occurred very much in the same way; that is, the rapidity of settlement, as Mr. Pruyn has described in the last diagram he had on the screen (Plate 63).

I have noticed the same thing in other buildings along the subway construction, but to further confirm the statement made previously that I do not think it is the lowering of the water which is responsible for the settlement so much as it is the bad soil and the temporary disturbance of the sub-surface conditions, I want to call your attention to some other buildings which have come to my attention. I know of two cases in other parts of the City where there has been no change in the water table, but the same kind of settlement has taken place, and can only be attributed, as far as I can see, to the movement of the pile foundation in the soil, because of the poor supporting power of the soil. Piles may be driven into a soil such as we find in Centre Street, that is, in the old Collect Pond, and along West Street—filled-in ground over silt—and driven so hard that they will broom, and yet after the load is put on them and the building is standing there for a while, further settlement will take place. There will be movement in the piles, and it becomes a serious question in some of the more important buildings which are placed on piles as to whether they are a suitable and proper foundation to put under a building where the sub-surface conditions are as above described.

Mr. F. L. Pruyn.—I would like to ask Mr. Miller a question. You state that the settlement in the Criminal Courts Building took place on the east side during the construction of the subway on the west side. How do you account for it? I do not quite understand how the disturbance could carry so far unless it had

something to do with the water which was removed from under the building by the pumping in the Elm Street Subway at the time of construction.

Mr. Miller.—The point I wanted to make was, that on the west side of the Criminal Courts Building the water was withdrawn as much as it was on the east side, but the material was better, so that if it were simply the withdrawing of the water, the building should have settled uniformly, but, inasmuch as the material on the east side was not as good as that on the west side, the withdrawal of the water there disturbed the sub-surface conditions, and because of the poorer material under the easterly end, the building settled more at that end. I don't doubt but that the entire building settled. We hadn't any way of checking that. We tried to get the original levels, but found that they were lost. The movement that took place on the easterly side, was simply a continuous movement which started from the very beginning, but during the subway construction on the west it was slightly accelerated, because of the sub-surface disturbance.

THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.

ADDRESS OF ROBERT R. CROWELL, PRESIDENT OF THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.

PRESENTED AT THE ANNUAL MEETING OF THE SOCIETY ON JANUARY 26, 1910.

Pursuant to Section VI of the Constitution and By-Laws it is incumbent upon the retiring President to make an address reviewing the progress of the Municipal Engineering work of the City of New York and the transactions of the Society. It has been the custom heretofore by my predecessors to reverse the order as set forth in the By-Laws, consequently, I will not depart from the beaten path.

It is a well-known fact and particularly so to the Municipal Engineers, that the past year has brought forth to public prominence the sterling qualities and executive talents of the municipal engineer.

The training of the Engineer along economical lines, and with limited means at hand, fits him for the difficult problems which confront him daily. These attributes stand him in good stead, as his advice is being sought on every hand by the officials of municipalities. While this condition may not have been brought about by this Society as a whole, still I venture to predict that it was brought about in a large measure through its members.

The engineering profession is destined to become a great power in the upbuilding of the municipalities and the government of this country. This cannot be better illustrated than in our own City to-day, where very few improvements are made without the advice of Engineers.

This Society was originally organized for the purpose of bringing together the various departments of the City, to endeavor to

promote sociability, good fellowship and to raise the standard of the profession in the City departments for the mutual benefit of its engineers. There is no reason to doubt its success, and it must be gratifying to the members to look back at the success which has been attained by their own efforts.

The detail work of the Society is more fully set forth in the annual report of the Board of Directors and of the various committees, and by these reports it can be seen that your Board of Directors and committees have been true to their trust and worked earnestly and efficiently for the success of the Society.

Meetings.

During the year eight papers were presented at the regular meetings, excluding the annual meeting; four were prepared and read by members and four by non-members. The papers and discussions were of a high order and show a great amount of careful work and study in their preparation. These papers are a large asset to the Society.

Annual Dinner.

The Seventh Annual Dinner was held at the Hotel Savoy on the evening of January 11th, 1910, and its success was largely due to the efficient work of the Chairman and members of the House Committee, supported by the members of the Society. Among the guests present were the President of the Borough of The Bronx and the President of the Borough of Richmond.

Excursions.

The excursions arranged by your Committee to points of interest to the Society about the City were pleasant and educating and were attended by large numbers of the Society and their friends, but it remained for the two excursions out of the City (Edison Cement Works at New Village, New Jersey, and the Ashokan Reservoir), to demonstrate the acute interest of the members in large engineering works. The large number of the members who availed themselves of the opportunity to inspect these works shows conclusively that the mere matter of cost will not deter them from attending excursions.

Membership.

I am extremely sorry to state that the books of the Society show an apparent loss in membership of eighty during the year, as the following figures will indicate:

Membership December 31st, 1908		595
Elected during 1909	43	
Elected during 1909 but did not pay dues	6	
Increase during 1909		37
		632
Elected previous to January 1st, 1909, but did not pay dues	40	
Resigned in 1909	25	
Dropped for non-payment of dues	49	
Deceased	3	
Decrease during 1909		117
Total membership December 31st, 1909		515

It can be seen from these figures that while there were 595 members credited to the Society on December 31st, 1908, there were 40 candidates on the roll who did not consummate their membership by paying their first semi-annual dues. Consequently they should not have been credited as members of the Society, on December 31st, 1908.

It has been the custom since the organization of the Society for the Directors to appeal to members in arrears to pay their dues, and in numerous cases this has had the desired effect. This custom has been stopped and the only appeal now made, is the notice from the Secretary. The dropping of the members for non-payment of dues, is a loss numerically, but a saving financially.

Why 75% of the eligible engineers in the City Service have not joined this Society before this time is beyond my comprehension, as there is no other Society in the City of New York in which the dues are so small and the benefits so large. The social opportunities are all that can be desired, and the opportunities for a free discussion of new ideas are always open at the meetings with an appreciative audience present.

The great interest of the present members of the Society is shown by the average attendance at the regular monthly meetings, which has been 130 for the past year. The maximum attendance was 174 at the September meeting.

FINANCES.

On January 1st, 1909, the cash balance on hand with the Secretary and on deposit in the bank was $1 060.46, and on December 31st, 1909, the balance in the hands of the Secretary and in the bank without any liabilities was $858.24.

This shows an excess of disbursements over the income of $202.22. In connection with this, I wish to call your attention to the fact that it has been necessary for the Society to pay for two *Proceedings* during the year, the cost of this extra *Proceedings* being about $1 000. If this extra drain had not been placed upon the Society, it would have shown an excess of income over the disburements. In addition to the above amount, the Society has a $2 000 New York City Bond, which pays 4½% interest. Consequently, I feel justified in stating that the finances of the Society are in excellent condition.

PENNSYLVANIA TUNNEL AND TERMINAL RAILROAD AND SUNNYSIDE YARD IMPROVEMENT.

Probably one of the largest improvements undertaken in the City of New York requiring the guiding hand of the engineer is that of the Pennsylvania Railroad Tunnels and Terminal.

The line starts at the Passaic River in Harrison Township, N. J., and runs adjacent to the present Pennsylvania Road until it reaches a point west of the shops of the Company on the meadows, where it deflects northerly along a new line until it strikes the divide between the Hackensack and the Hudson River, known as Bergen Hill. Thence it passes through two rock tunnels to and under the Hudson River to the Terminal Station in Manhattan, thence by four tunnels through Thirty-second and Thirty-third Streets, and under the East River to Long Island City, terminating at what is called the Sunnyside Yard.

The following are the lengths of the different sections: From Harrison to the portal of the tunnels in New Jersey 6 miles; from the portal in New Jersey to the Pennsylvania Station 15 500 ft.;

from the Pennsylvania Station to the portal in Long Island City 14 000 ft. The two tunnels under the Hudson River were each shield-driven 6 000 ft., while the four tunnels under the East River were each shield-driven 5 700 ft. The lowest point of the top of the tunnels is 70 ft. below the surface of the Hudson River and East River, respectively.

Provision has been made in laying out and constructing the Sunnyside Yard for a physical connection with the New York Connecting Railroad, which in turn will connect with the New York, New Haven and Hartford Railroad.

The progress of the construction of the Pennsylvania Railroad Tunnels and Terminal has been exceptional. All the work on the line between Harrison, New Jersey, and the Terminal Building, in Manhattan, and from the Terminal to Long Island City, including the track laying, has been completed. The installation of the interlocking system of switches and signals is progressing very rapidly, after which the road can begin operations.

The beautiful Terminal Station, located between Thirty-first and Thirty-third Streets, Seventh and Ninth Avenues, is practically completed, there being only a small amount of cleaning to be done preparatory to installing the fixtures. The beauties, convenience and magnitude of this building cannot be adequately described, as it must be seen to be appreciated. The following are some of its principal features:

The style of architecture is Roman Doric. The station covers $7\frac{7}{10}$ acres, while the station and yard cover $27\frac{8}{10}$ acres. The building has a frontage on the avenues of 430 ft. and on the streets 780 ft. The maximum height of the building above the street level is 157 ft., while the external walls are 60 ft. above the street. The main entrance arcade is 225 ft. long and 45 ft. wide leading into the general waiting room, which is 320 ft. long, 110 ft. wide and 150 ft. high, with subsidiary waiting rooms 100 ft. long and 58 ft. wide.

The tracks are located 45 ft. below the elevation of the street, there being 21 tracks with a total of 17 miles, and $2\frac{87}{100}$ miles of platforms. Three hundred eighty-six coaches can be stored in the station.

This improvement necessitated great modifications in the street

system of the City and more particularly in the Borough of Queens, where the Company has laid out a tract of land over 1½ miles long and ¾ mile wide for a storage and terminal yard. This necessitated the elimination of streets across the line of the company's yards and required the erection of four highway bridges over the yard at Thomson Avenue, Queens Borough Bridge Approach, Honeywell Street and Harold Avenue.

The bridge at Thomson Avenue is 773 ft. long, 60 ft. roadway and two 10-ft. sidewalks. The Queens Borough Bridge Approach is 1 036 ft. long, 60 ft. roadway and two 10-ft. sidewalks, with 3½ ft. additional on each side for pipe supports. The Honeywell Street Bridge is 1 575 ft. long, 42-ft. roadway and two 10-ft. sidewalks. The Harold Avenue Bridge is 889 ft. long, 42-ft. roadway and two 10-ft. sidewalks. The construction of these bridges was at the expense of the railroad company with the exception of the approach to the Queens Borough Bridge, of which the City agreed to pay one-half the cost of construction.

The total amount of excavation within the yard limits is 2 737 760 cu. yd. The main tracks will amount to 13.56 miles, while the yard tracks amount to 39.62 miles. This work is practically complete with the exception of a small amount of track to be laid, and the installation of the interlocking signal system.

The yard has many unique features, such as the provision for running all trains around a loop, pulling them into the coach cleaning yard at one end and departing from the other end, thus turning the entire train and avoiding the necessity for switching baggage and sleeping cars to opposite ends of the trains and the turning of combination cars separately. The arrangement of tracks on different levels makes provision for cross-over movements without grade crossings and eliminates interference with high speed traffic by switching movements.

The magnitude of this work is indicated by the approximate estimate of the cost of the different sections:

From Harrison to Pennsylvania Station	$25 000 000
From Pennsylvania Station to Long Island City	45 000 000
Station and Terminal Yard	35 000 000
Sunnyside Yard	10 000 000
Total	$115 000 000

DEPARTMENT OF TAXES.

The Department of Taxes and Assessments prepared and published for the first time, Land Value Maps, showing on every block frontage of the City the value per foot front of normal lots 100 ft. deep. The assessment of real estate is based on a system of permanent maps, which at the end of the year 1909, cover the Boroughs of Manhattan and Brooklyn and the Borough of the Bronx west of the Bronx River. In the remainder of the City, the assessment is based upon tentative maps.

The assessed valuation of taxable property for the year 1909 was	$7 250 500 559
The assessed valuation of property exempt from taxation for the year 1909 was	1 297 301 451
Total	$8 547 802 010

BOARD OF ESTIMATE AND APPORTIONMENT.

During the year the Board of Estimate and Apportionment adopted a resolution fixing the widths of roadways and sidewalks for all streets and prescribing the minimum distance between curb lines, for streets in which are located either single track or double track surface railroads. This will make it necessary where surface railroads are hereafter constructed, to widen the roadways, if necessary, to comply with this ordinance, and it is hoped that it will eventually discourage the location of surface railroads on narrow streets. At the same time a resolution was adopted which was designed to prevent further encroachments upon public streets by stoops, steps, areas or any other construction for the private use of any portion of a public highway by the abutting owner. This action called forth vigorous protests on the part of builders, real estate owners and title companies, and this resolution was declared inoperative in the hope that a substitute resolution could be drawn, which, while putting a stop to the abuses which have gradually grown up, would at the same time not interfere with suitable architectual treatment of buildings and with reasonable facilities for ingress and egress. The problem proved to be so difficult of solution that the resolution of April 23d, so far as it related to encroach-

ments, was rescinded on December 23d, and it is expected that this matter will be taken up by the new Board of Estimate and Apportionment.

The question of paying for slight encroachments of buildings and for stoops, steps and fences in acquiring title to streets, has also been the subject of conference with the Corporation Counsel in the hope that it might be possible to avoid the enormous addition to the cost of street opening proceedings, which are involved in making awards for a few inches of a building falling within the street lines, when it has been almost invariably the practice to allow such slight encroachments to remain after they have been paid for at a substantial figure, and it was hoped that it might be possible to acquire title to such small areas, subject to easement, which would permit the owner to continue to occupy these few inches of the street until the building could be remodeled or replaced by a new structure, when it could be placed upon the proper building lines. The Law Department appears to be doubtful of such a policy, desirable as it may seem.

A typical case illustrating the difficulty of securing satisfactory foundations for large buildings on certain portions of the Borough of Manhattan, is presented in connection with the proposed new Municipal Office Building, in the basement of which will be the station for the Rapid Transit Subway now being built in Center Street. The first plan contemplated the placing of these foundations on sand, with unit loads of 8 tons to the square foot. It was subsequently though desirable to carry the foundations to rock, which, from test borings which had been made, was believed to be about 100 ft. below tide water. New plans were accordingly made and a contract awarded. As the work progressed it was found that for about one-third of the area of the building the rock was much more than 100 ft. below tide, while in certain places it was approximately 180 ft., which is far beyond the practicable limit for pneumatic work. Meanwhile a number of the caissons had been carried to rock, and the question arose as to the advisability of placing two-thirds of this high building upon a rock foundation and the remaining one-third upon sand, with the caissons enlarged so as to reduce the unit loads to 6 tons per square foot. This latter plan was finally adopted.

The following shows the surface and sub-surface improvements authorized by the Board of Estimate and Apportionment in 1908 and 1909:

SURFACE IMPROVEMENTS. SEWER IMPROVEMENTS.

Boroughs.	Surface: Total in 1908.		Surface: Total in 1909.		Sewer: Total in 1908.		Sewer: Total in 1909.	
	No.	Amount.	No.	Amount.	No.	Amount.	No.	Amount.
Manhattan....	16	$105 700	20	$451 000	15	$88 200	12	$52 500
Brooklyn	90	792 000	108	858 200	91	696 800	89	686 600
Bronx.........	19	560 500	69	1 556 400	36	364 000	17	200 100
Queens........	14	179 800	20	861 500	20	91 600	16	121 300
Richmond	......	....	6	25 200	8	81 000	18	406 400
Total......	139	$1 637 500	223	$3 247 300	170	$1 315 100	152	$1 466 900

The total physical improvements and street and park opening proceedings authorized, with an approximate estimate of the cost, in 1908 and 1909 are as follows:

Borough.	Improvements. 1908.		Improvements. 1909.		Street and Park Opening Proceedings. 1908.		Street and Park Opening Proceedings. 1909.	
	No.	Amount.	No.	Amount.	Number of streets and parks affected.	Number of proceedings.	Number of streets and parks affected.	Number of proceedings.
Manhattan.............	31	$187 900	32	$503 500	12	7	13	9
Brooklyn...............	181	1 458 300	197	1 539 800	129	67	66	42
Bronx...................	55	924 500	86	1 756 500	65	36	51	26
Queens..................	34	270 900	36	482 800	16	13	43	24
Richmond	8	81 000	24	431 600	3	3	5	5
Total.............	309	$2 952 600	375	$4 714 200	225	126	178	106

The Board has authorized the issue of Corporate Stock for the purposes mentioned below in the following amounts during the past year:

Topographical Work	$606 000.00
Land for Bridges	3 685 657.15
Park Improvements	2 233 612.81
Repaving	3 000 000.00
Improvement Water Supply	2 516 849.66
Aqueduct Commissioners	1 000 000.00
Board of Water Supply	41 000 000.00
High Pressure Fire Service	920 000.00
Rapid Transit	1 905 000.00
Public Buildings	9 688 600.00
Libraries	1 047 000.00
School Buildings and Land for same	1 834 000.00
Water Front	31 141.33
Bridges	1 216 682.62
Change of Grade Commission	891 850.00
Salaries (Board of Education)	100 000.00
Jamaica Bay Commission	75 000.00
Fire Alarm	107 000.00
Sewer Construction	200 000.00
Crematories	32 500.00
Subways	15 876 381.10
Street Openings	5 883 513.46
	$94 050 788.13

FINANCE DEPARTMENT.

During the year 1909, 3 200 contracts were certified by the Comptroller, amounting to $65 000 000, and 7 782 claims were investigated, amounting to $48 676 545.

BOARD OF WATER SUPPLY.

During the year 1909, sixteen contracts for the construction of the Catskill Aqueduct to the amount of $28 397 000 were awarded. The total value of all main contracts, which have been awarded to date, is $54 462 000. The total length of the aqueduct under contract is 77 miles. Contracts for the balance of the aqueduct to Hill View Reservoir (covering about 16 miles) are either in process of preparation or under advertisement.

Included in the work of the contract are the main dams and Hurley Dikes of the Ashokan Reservoir, and also the Hill View Reservoir. The sinking of the shafts on opposite sides of the Hudson River has been prosecuted by the Board's forces, and inclined borings from the two test shafts toward the center of the river, have progressed in an entirely satisfactory manner. The borings in the center of the river, at the Hudson River crossing, have reached a depth of 697 ft.

The total amount of work done under all main contracts has been $9 300 000. The total value of work done during the current year has been $7 181 000. Excellent progress has been maintained on practically all of the contracts, and in general, the work is well in advance of contract requirements.

On November 15th, the Board of Water Supply made application to the Board of Estimate and Apportionment for the approval of a modification of the plans of October 9th, 1905. Said modification provides for the delivery of the Catskill water to the several boroughs of the City. This plan calls for a tunnel deep in the rock from Hill View Reservoir, under the Borough of the Bronx and flowing practically under the entire length of Manhattan Island, crossing under the East River between the Manhattan and Williamsburg Bridges to a point in Brooklyn, where metal pipes will extend to the Boroughs of Queens and Richmond. The plan contemplates connections into the present distribution system at various points, and through these connections, water will be allowed to pass through pressure regulators at whatever pressure may seem most advisable. The plan was approved by the Board of Estimate and Apportionment on December 10th, 1909.

The total force of the Engineering Bureau of the Board of Water Supply on December 1st, 1909, was 1 065. This figure includes gage-keepers, laborers and miners employed in sinking shafts of the Hudson River.

AQUEDUCT COMMISSIONERS.

During the past year the construction of the Croton Falls Reservoir of the "Croton System" has progressed very satisfactorily. This construction embraces a large masonry dam across the west and middle branches of the Croton River, north of Croton Falls, and

an earthen dam across the east branch of the Croton River, south of Brewster, forming two storage reservoirs, one of 14 192 mil. and the other 891 mil. gal. capacity. These two are connected by a paved channel ⅔ mile long. In connection with the above, there are being constructed a system of highways 14½ miles long to replace old highways, which are to be flooded, and 20 miles of boundary walls. An area of 1 627 acres is now being cleared and made ready for the storage of water.

The work has been energetically pushed forward during the year. The main dam now being built to and including the roadway across it, with the overflow dam (700 ft. long) and spillway, together with the waste channel and other appurtenances are being constructed and are well under way. The earth dam together with its thousand ft. spillway has been built to within about 15 ft. of its top, while its channel and other appurtenances are well along towards completion. The connecting channel between the two reservoirs is completed, except the three tunnels which are to carry the water under the Harlem Railroad tracks, which tunnels are now being driven. Some water has been stored back of the dams during the past year. The amount of work done during the year for the Croton Falls Reservoir amounts to $1 600 000.

Emergency cross-gates were designed and are being put in at Gate House No. 1, Jerome Park Reservoir, and at the One Hundred and Thirty-fifth Street Gate House, which will give better control of the working of the supply to the reservoirs and pumps. Gates and screens at the New Croton Dam, superstructures for seven gate chambers at Jerome Park Reservoir, a blow-off from the Goulds swamp siphon of the new aqueduct to empty the same when desired have been designed and are under construction. The total cost of the above work will be about $650 000. During the past year, while installing gates at Jerome Park Reservoir and One Hundred and Thirty-fifth Street, it became very apparent that more storage capacity should be had within the limits of the City, as it is not safe to shut off the aqueduct for any purpose for more than one day. The relief for the City in case of emergency is the finishing of the easterly basin of Jerome Park Reservoir, which has been held in abeyance for the purpose of considering the advisability of constructing a Filtration Plant at that point.

DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY.

Boroughs of Manhattan and The Bronx.

The consumption of Croton and Bronx water has remained stationary during the past year at an average of 325 mil. gal. daily; in fact, there has been no increase in consumption during the past four years. The usual course has also been followed in having practically all the storage reservoirs filled during the early part of the year, there being 86 000 mil. gal. of water on hand at the end of May. This amount was reduced during the Summer and Fall to 40 000 mil. gal. at the end of the year.

The sewage disposal plant at Mount Kisco is now under construction, both disposal plant and pumping station being constructed by the City of New York, and the Town building the sewers.

The high pressure fire system has been in active service during the past year, having been put to a very severe test on January 7th, when five fires were in progress simultaneously, to which 600 firemen responded. During these fires the stations supplied water at the rate of 33 500 gal. per minute for a considerable length of time, at a pressure of 225 lb. at the station and 210 lb. at the hydrants. This quantity of water was in excess of the rated capacity of the two stations combined and was supplied with but seven of the 10 pumps in service, to wit: Four at the Oliver Street Station and three at the Gansevoort Street Station.

Contracts have been let for four extensions to the present high pressure fire system, at an estimated cost of over $1 500 000, work on which is being actively prosecuted in the field and at the pipe foundries.

The Department has taken up with the Board of Water Supply the question of the necessary remodeling of the distribution system to conform to the greater head available when the Catskill supply is delivered to the City. This increased pressure will require an increased thickness of the mains and an entire re-arrangement of the main arteries, as the Catskill water will be available through the proposed pressure tunnel under the City at a number of uptakes instead of as at present being delivered entirely at one end of the City.

In the low pressure system over 30 miles of low pressure water

mains were laid during the year, 1 260 valves and 750 new hydrants were set, and a large number of old hydrants were replaced by those of more modern pattern.

BOROUGH OF BROOKLYN.

During the year a new driven-well station, within the borough, was completed and put into operation. The capacity of this new station is 5 mil. gal. per day; its average yield at present is 3.5 mil. gal. The buildings for three new driven well stations in the watershed have been completed, and contracts awarded for the installation of the necessary machinery in the same. The capacity of these stations will be about 3 mil. gal. each, daily.

For the purpose of increasing the pumping capacity at the Ridgewood Pumping Station, the North Side Plant is being remodeled and extended at a cost of $375 000. In this station, when completed, there will be erected four pumping engines, with a combined capacity of 76 mil. gal. per day, and eight 300-h.p. water tube boilers. The cost of the pumping engines, boilers and steam fitting will be about $404 000.

A new 72-inch steel pipe line is being laid from Valley Stream to Amityville, Long Island. The cost of the work will be approximately $1 880 000.

During the year 15.6 miles of the 72-in. pipe and approximately 2 607 lin. ft. of smaller pipe, varying in size from 48 in. to 6 in., were laid and 81 valves set.

During the year the work of extending the distribution system progressed very rapidly. 26 miles of new mains were laid, 443 new valves were set and 611 new hydrants placed. 2.8 miles of new pipe were laid in various streets to replace old and smaller pipes. 227 new valves and 81 new hydrants were set in place of old ones.

The old tuberculated mains in many streets were cleaned under contract, the amount of work of this character being as follows:

36-in. pipe cleaned	19 200 lin. ft.
30-in. pipe cleaned	22 000 lin. ft.
20-in. pipe cleaned	1 300 lin. ft.
12-in. pipe cleaned	3 600 lin. ft.
8-in. pipe cleaned	24 600 lin. ft.
6-in. pipe cleaned	29 200 lin. ft.
	= 18.9 miles.

Contracts have been advertised for the laying of two 48-in. trunk distributing mains for the improvement of the water supply through various wards of the borough. They call for the laying of 35 000 ft. of 48-in. pipe and 19 300 ft. of smaller pipe. The cost of these two contracts will be approximately $700 000.

The high pressure fire system at Coney Island has been extended at a cost of about $75 000, the work done being as follows: 19 000 lin. ft. pipe laid, 189 valves set, 74 4-nozzle hydrants set, 19 3-nozzle hydrants set, 3 monitor nozzles set.

Plans and specifications have been completed and the contract is about to be advertised for the extension of the main high pressure fire system into the Gowanus and South Brooklyn sections of the borough at an approximate cost of $700 000. Under this contract 13.1 miles of new high pressure mains will be laid.

Borough of Queens.

Careful tests have shown that no more water can be obtained from the three pumping stations now operating in the first ward of the borough. Since the City has a contract with the Citizens Water Supply Company made in 1898, for the supplying of this ward, the improvements have been made along the lines of increased supply from other sources, and better distribution within the limits of the first ward.

A contract has been awarded for a 30-in. main along the Hoffman Boulevard, which will enable the City to secure an additional 10 mil. gal. daily from it, and the distribution of this water throughout the various sections of Long Island City has been provided for by an appropriation of $364 000, which was authorized in the early part of last year.

This main will be one of the permanent features of the distribution system in the borough, as it will be a main distributing line for the water from the Catskills that will eventually be used to supply this borough.

A contract for filter beds at the Bayside Pumping Station has been let at an estimated cost of $26 378. The work has progressed, up to the present time, quite rapidly, and the excavation is nearly completed. These filters have a capacity of about 2 mil. gal. daily, and, it is estimated that the lake will furnish about 1.5 mil. gal.

Two new deep wells have been completed, one being about 388 ft. and the other 412 ft. deep; the first giving about 0.3 mil. gal. and the latter about 0.5 mil. gal. per day.

Contracts have been awarded for two new 4 mil. gal. triple expansion direct acting pumps, a new intake well, including all suction pipes for the new pumps, the deliveries from the filters, and also for five new deep wells.

When these contracts are completed, this station will have an estimated supply of 2.5 mil. gal. from the wells and 1.5 mil. gal. from the filters, with pumps in duplicate for pumping the same. The present Blake pump of about 2 mil. gal. capacity will also be retained in commission, giving a total pumping capacity of about 10 mil. gal.

In connection with the filters, a small laboratory has been constructed and a laboratory assistant, under the Director of Laboratories, but reporting to the Queens Office, will be stationed there, and will take daily samples of the lake water, up to the time the filter is finished, and, thereafter, samples will be taken each day and tested, to determine the efficiency of the filters.

Samples of the deep well water have shown it to be of excellent quality, and it comes from a depth that precludes all possibility of contamination.

METROPOLITAN SEWERAGE COMMISSION.

The Metropolitan Sewerage Commission of New York is a special Board of Engineers, created by the City and State of New York, to investigate the question of sewage disposal as it relates to the Metropolitan District of New York and New Jersey, to set at rest, as far as possible, the many uncertainties which have existed heretofore with regard to this subject. Aware of the magnitude of the problems to be solved and of the far-reaching effects which may follow its work, the Commission is making every effort to make its investigations thorough, adequate and authoritative.

The Commission is making extensive examinations of the waters of the harbor, with relation to sewage pollution and their digestive capacity for sewage. Studies are being made of the sewerage systems of New York City and municipalities within a distance of about twenty-five miles. The possibility of using other methods

than those at present employed for the sewage disposal in the Metropolitan District of New York is being investigated. Forecasts of population for the municipalities within the Metropolitan District of New York and New Jersey are being made with much care, due regard being had for the estimates of future population which have been made by others.

It is the aim of the Commission to have the final report made before May 1st, 1910.

DEPARTMENT OF DOCKS & FERRIES.

During the year eight large double-deck steel freight sheds, together with their lateral inshore extensions, with handsome masonry fronts were completed, and the same equipped with an up-to-date electric lighting, power and steam-heating plant, between West Twelfth Street and Twenty-third Street, North River, commonly known as the Chelsea Section. The shed on the remaining pier of the Chelsea Section, near the foot of Little West Twelfth Street, is now in course of construction, and in all likelihood will be completed in about three months.

It may be stated that this practically completes what is probably the costliest single improvement ever attempted by the City in water-front construction, amounting in round figures to about $24-000 000, which embraces the value of the land acquired and its subsequent removal in order to make long piers, and the construction of nine piers and a marginal street.

Another important work of improvement is that of the Gowanus Section in the South Brooklyn District, where piers ranging from 1 000 ft. to 1 600 ft. in length are under construction. This improvement involves the removal of 3 500 000 cu. yd. of material. One pier about 1 450 ft. in length and 150 ft. wide, having a reinforced concrete deck, has been completed, and the work of erecting a steel shed thereon is now in progress. Plans, specifications and studies have been prepared for the construction of additional piers in this section near the foot of Thirtieth, Thirty-third and Thirty-fifth Streets, and the contract for the Thirtieth Street pier will be awarded within a short time.

At Whale Creek, which is an off-shoot of Newtown Creek, an extensive improvement is in progress, dredging for which has been

completed. This work involves the construction of a considerable length of bulkhead walls and piers projecting from the same.

The Ferry Houses at the Manhattan Terminal for the Thirty-ninth Street Ferry of Brooklyn and for the Staten Island Ferry have been completed, and there is no doubt that they are the handsomest and costliest ferry structures ever erected.

Two hundred ninety-four thousand ninety-one square feet of pier and platform room were made and 1 280 lin. ft. of bulkhead and river wall were built by Departmental labor during the year.

JAMAICA BAY IMPROVEMENT COMMISSION.

In the early part of 1909, a report on the proposed improvement of Jamaica Bay and the entrance thereto, was submitted to the War Department by Colonel John G. D. Knight. This report was a favorable one and recommended that the improvement of the Rockaway Inlet be undertaken by the Federal Government, and that, furthermore, the Government should likewise make an appropriation for the dredging of the main channel in Jamaica Bay, extending from the southeast corner of Barren Island, north and east along a suggested pierhead line, for a distance of over 43 000 ft. to the outlet of Cornell's Creek. This report practically recommended that the United States Government should commit itself to this improvement to the extent of something over $7 000 000, upon condition that the City of New York would co-operate in the enterprise. In March of this year, the report of Colonel Knight was acted upon favorably by the Board of Engineers for Rivers and Harbors, the only change made by that Board being a reduction of two cents per cubic yard in the recommended allowance for the dredging of the main channel referred to above. In consequence of a report upon these matters by the Jamaica Bay Improvement Commission, the Board of Estimate and Apportionment appropriated $75 000 for the use of this Commission, in making surveys and estimates and for the preparation of a harbor-line plan so that the City authorities would be in a position to determine to what extent and at what cost the City of New York should co-operate in the improvement of the bay. This appropriation was made on July 2d, 1909, and since that time the Commission has been engaged in making the necessary topographic and hydrographic surveys of the bay, and in

making such necessary surveys as would enable them to properly prepare the bulkhead and pierhead line plans.

The surveys made by this Commission, among other things, embraced a new plane table survey of about 4 500 acres of meadow land and small creeks on the west and north shores of the bay in the Borough of Brooklyn. In addition to this the Commission was enabled, by virtue of these surveys together with some triangulation work conducted at the same time, to establish harbor lines with accuracy and to determine the exact position of a considerable number of additional triangulation stations throughout the bay, all of which will later be found useful in conducting such hydrographic surveys as are necessary to procure data from which complete plans of the bay may be drawn. On the 27th day of December, the Commission submitted a report to the Board of Estimate and Apportionment for its approval.

DEPARTMENT OF BRIDGES.

On March 30th, 1909, the Queensborough Bridge was opened to pedestrians and vehicular traffic, and on September 19th, the City began the operation of surface cars across the bridge, since which time the paving and electrical work on the bridge and approaches have been completed. The bridge, as built, has on the upper floor two sidewalks, each 16 ft. wide, and provision for two elevated railway tracks. On the lower floor between the trusses there is a roadway 53 ft. wide upon which are two surface railway tracks, one track on each side of the roadway, and outside of the trusses are two surface railway tracks.

The erection of the Manhattan Bridge over the East River has progressed in a very satisfactory manner. The cables, which were strung in 1908, were wrapped and the suspenders attached and the suspended superstructure completed. The erection of the steel and masonry approaches is nearly completed. A contract for the railings, roadway and footwalk pavements, track and electrical equipments of the bridge was let in June, and this work is well advanced.

The bridge will have on the upper floor, four railway tracks. On the lower floor there will be two sidewalks, each 11 ft. wide,

a roadway 35 ft. wide, and four railway tracks. This bridge was opened to traffic on December 31st, 1909.

The Madison Avenue Bridge which connects Madison Avenue and One Hundred and Thirty-eighth Street in the Borough of Manhattan with One Hundred and Thirty-eighth Street in the Bronx, is being pushed in a vigorous manner, The piers and abutments are completed. The draw span has been erected, and the work on the approaches is well advanced. The bridge is a swing bridge with a span of 300 ft. and has three trusses. The length of the bridge, including side spans but not approaches, is 484 ft. There will be two surface car tracks on the bridge.

A contract has been awarded for the construction of a bridge on Hunters Point Avenue over Dutch Kills, in the Borough of Queens, at an estimated cost of $95 214. The bridge is of the double-leaf bascule type with a clear span of 50 ft. The total length of the bridge, including the side spans but not the approaches, is 150 ft. The dredging has been completed and work has progressed on the piers and abutments.

In June last, a contract was awarded for the construction of the foundation of the Municipal Building at an estimated cost of $1 443 147. The location of the building is at Tryon Row, Centre Street, Duane Street and Park Row, in the Borough of Manhattan. The building will be a steel frame structure, faced with granite, and will be twenty-five stories in height, surmounted by a fourteen-story tower. The excavation of the site has been completed and the caissons are now being sunk.

NEW YORK INTERSTATE BRIDGE COMMISSION.

The New York Interstate Bridge Commission, in co-operation with a similar Commission in New Jersey, was created for the express purpose of locating sites for bridges across the Hudson River, in the vicinity of Fifty-seventh Street, One Hundred and Tenth Street and One Hundred and Seventy-second Street in the Borough of Manhattan. Nothing definite has been done in the past year, owing to the failure of the State of New Jersey to comply with New York State's conditions, pursuant to an Act passed by the New York State Legislature in 1909.

PUBLIC SERVICE COMMISSION FOR THE FIRST DISTRICT.

The Bureau of Design has had under consideration for the past year, a large number of plans for the extension of the present lines and the increasing of the present elevated and subway facilities with the object in view of increasing the carrying capacity of all the transit lines, by connecting the four-track and double-track subways, and by three-tracking the elevated railways, thereby increasing the trackage by 90 miles of subway, and more than 30 miles of elevated railways at an aggregate cost of $150 000 000. Plans have been prepared for the extension of the subway system through the Boroughs of Manhattan, Brooklyn and the Bronx to ultimate terminals in the Boroughs of Queens and Richmond.

The Broadway and Lexington Avenue route extends from the Battery through Church Street, Broadway, Lexington Avenue, Mott Avenue and Jerome Avenue to the City's northern limits, with a branch to Pelham Bay Park. For its greatest length in Manhattan, it will be a four-track route, while the two branches will have three tracks each. Another route has been proposed under Canal Street from Manhattan Bridge to the North River. This route will be practically for the transfer of passengers from one north and south subway to another.

Another route which has been laid out is known as the Broadway and Lafayette Avenue route. This will operate in a loop from Brooklyn over the Manhattan Bridge and returning over the Williamsburg Bridge. This will be operated in conjunction with the subway now building on Centre Street. A design has been made to extend what is known as the Fourth Avenue Tunnel in Brooklyn to Fort Hamilton and Coney Island, with a provision for a spur to Staten Island. On October 29th, 1909, the Board of Estimate and Apportionment passed a resolution which permitted the construction of the Fourth Avenue Tunnel, and on which the contractors are now at work.

The subway bridge loop in the Borough of Manhattan, connecting the Williamsburg and Manhattan Bridges to the Brooklyn Bridge has been practically completed. This line will enter the new Municipal Building, which is located at the intersection of

Park Row and Centre Street. The foundation for this building was started over a year ago, but was interrupted on account of a change in the plans. Recently work was started upon the foundation, and the work is now progressing very rapidly.

New stations are being constructed at St. Nicholas Avenue, One Hundred and Eighty-first and One Hundred and Ninety-first Streets. These stations are to contain spaces for four elevators and a stairway and will be 183 ft. deep. In November last, work was begun for the installation of an inclined elevator at a station located at One Hundred and Seventy-seventh Street. The work has been completed for the shuttle-train service between South Ferry and Bowling Green, and was put into operation the first part of last year. Permission was obtained and money appropriated by the Board of Estimate and Apportionment, to the extent of $1 150 000, for the lengthening of the subway stations and platforms, so that they would accommodate ten-car trains.

Numerous claims have been made by contractors for extra work upon their contracts. These claims are now before the Board of Arbitrators for final adjudication. This requires the services of a large part of the engineering force on account of the intricacy and the amount of the claims.

The Continuous Transit Security Company applied to the Public Service Commission for an opportunity to demonstrate the value of moving platforms, as a means of transit facility within the City. The said Company made application for different routes. Route No. 1 extends from the Williamsburg Bridge Plaza over the bridge, through Delancey Street, Centre Street, Park Row, Nassau, Broad and Beaver Streets, to the present subway. Route No. 2 is through Nassau and Pearl Streets in Brooklyn, thence across the Manhattan Bridge to Canal Street and Watt Street, thence to terminate in a loop. Route No. 3 extends from Nassau and Washington Streets across the Brooklyn Bridge, crossing the City Hall Park, and through Warren, Church and Vesey Streets to a loop near West Broadway. Route No. 4 begins at Fourth Avenue and Fourteenth Street, and extends along Broadway to Forty-second Street. Route No. 5 is a crosstown subway on Thirty-fourth Street from Second to Ninth Avenue. Route No. 6 is a crosstown subway on Fourteenth Street, from Avenue A to Ninth Avenue. Route No. 7

is a crosstown subway on Twenty-third Street from the North to the East River. Route No. 8 extends from the Eastern Plaza of the Queensborough Bridge across said bridge to Manhattan, and along Fifty-ninth Street to Fifth Avenue. This application was referred to the Chief Engineer, in March, 1909, for a report. The Chief Engineer of the Commission made an exhaustive report relative to this matter, and recommended that the routes be laid out as requested, and that installation of some one of these routes be made at as early a date as possible. The application was made by the Continuous Transit Security Company to the Board of Estimate and Apportionment, on November 17th, 1909. A Select Committee recommended the construction and operation of the Thirty-fourth Street Route, and the Board of Estimate and Apportionment approved the same on December 5th, 1909.

In February, 1909, the Hudson and Manhattan Railroad Company applied to the Commission for an extension of their line on Sixth Avenue northward to Fortieth Street, thence under Bryant Park to Forty-second Street and east to the Grand Central Station. This application was approved by the Commission in May, and by the Board of Estimate and Apportionment in June, pursuant to an agreement that this Company was to use only the southerly half of Forty-second Street, leaving the remainder for the extension to the Steinway Tunnel.

HUDSON AND MANHATTAN RAILROAD COMPANY.

The downtown system of the tunnels of the Hudson and Manhattan Railroad Company, crossing the North River at the foot of Cortlandt Street "holed through" on January 27th, and at the foot of Fulton Street on March 11th. The total progress of the work during the year was 1 018 ft. The underground portion of the open cut approaches in the Hudson Terminal Building was completed during the year, as well as the fittings, station facilities and tracks in the concourse floor, in order to make this available for use as a railroad station. On July 19th, after appropriate ceremonies and celebration in Jersey City, the railroad was opened to the general public. At the Pennsylvania Railroad Station, in Jersey City, four large plunger elevators were built, and two were constructed to the street surface. At the Erie

Station, two plunger elevators were constructed to the street surface. Work is being continued on the extension of this line westerly on Railroad Avenue in Jersey City and on Sixth Avenue between Twenty-third and Thirty-third Streets, New York.

THE LONG ISLAND RAILROAD.

During the year the Long Island Railroad Company has completed what is known as the Glendale Cut-off, with the exception of a small amount of track-laying. This connection is made between the Rockaway Beach Line and the Main Line, and will provide for the carrying of passengers from the Beach through the tunnels under the East River to the Pennsylvania Station in Manhattan.

The Montauk Freight Cut-off and Overhead Freight Line in Long Island City connects the North Shore Freight Yards at the west end of the Sunnyside Yards with the Montauk Division. All of the work has been completed, with the exception of the Dutch Kills Lift Bridge now being erected and a bridge over Meadow Street.

One of the most important pieces of work constructed last year was the re-construction of the Main Line of the Long Island Railroad between Jamaica and Winfield. This work has involved some improvement of alignment of the tracks, the readjusting of the grade line of the railroad to conform to the City maps, the construction of a number of bridges over and under City streets, all in conformity with the ultimate street widths. The future requirements have necessitated the construction of four tracks from Jamaica to the Glendale Cut-off, and six tracks from the Glendale Cut-off to Winfield.

The Company is now at work on the electrification of the Main Line from Long Island City to Jamaica, with a new electric substation located at Winfield.

BROOKLYN GRADE CROSSING COMMISSION.

The Brighton Beach Improvement.

Contracts have been awarded to open street crossings at Avenue L and at Avenue P on the right of way of the Brighton Beach Improvement. This work has just been started and it is intended to have the same completed about May 1st, 1910.

THE BAY RIDGE IMPROVEMENT.

The work on this improvement is progressing very rapidly as is shown by the following figures of work done:

Masonry of all classes..	10 700	cu.	yd.	$65 600.00
Foundation excavations..	14 000	"	"	12 750.00
Excavation	182 000	"	"	41 500.00
Total				$119 850.00
Permanent track laid				29 000 ft.

The above excavation was placed on the Manhattan Beach Branch between Avenue N and Manhattan Beach Terminal.

The following railroad bridges were completed and put in service during the year: Avenue N, Kings Highway, Avenue S, Avenue U, Neck Road, Avenue Y, Avenue O, Avenue R, Avenue T, Avenue V, Brooklyn Rapid Transit Inclines, Shore Road and Neptune Avenue. The payments made during the year for the steel superstructures was $37 200.

GRAND CENTRAL TERMINAL STATION.

This improvement started in August, 1903, and, while the plans were complete at that time, conditions and methods have changed, consequently it has been necessary to modify the plans.

The present building, which is partly completed, will be seven stories above the street level, with provisions to build it to a height of twenty stories above the sidewalk.

There will be two planes for the arrival and departure of trains, the first, which will be below the street level, will be solely for express train service, while the second level will be wholly for suburban traffic. It will have a double loop, which will allow the rapid handling of trains without the shifting of motor and baggage cars. The whole station will be equipped with high platforms.

This improvement will allow the extension of Park Avenue south from Fifty-seventh Street and Forty-fifth Street, and all the cross streets between Forty-fifth Street and Fifty-seventh Street from Lexington Avenue to Vanderbilt Avenue with a maximum grade of 4%.

It is proposed to close Depew Place and to have Forty-fifth, Fifty-third, Fifty-fourth and Fifty-fifth Streets open by the first of 1911.

The following is an approximate estimate of the quantities in this improvement and the percentage completed:

1 031 000	cu. yd.	Unclassified excavation	59%
1 600 000	"	Rock excavation	51%
250 000	"	Concrete	39%
60 000	tons	Steel	33%

The City has agreed to assume a portion of the cost of the construction of the viaducts on the line of the streets crossing the yard of the Railroad Company. This will amount to approximately $850 000.

DEPARTMENT OF EDUCATION.

The following is the total number of school sittings and the total registration upon December 31st, 1909, also the total increase of school sittings and the total increase in registration during the year 1909:

Total number of school sittings Dec. 31st, 1909,	704 013
Total increase of school sittings during 1909	23 553
Total registration December 31st, 1909	661 988
Increase in registration during 1909	22 939
Estimated value of school property, July 31, 1909	$122 405 677

TOPOGRAPHICAL BUREAUS.

Borough of Brooklyn.

The Bureau is now at work preparing a new grade chart for the entire borough, which is a work of large magnitude. During the past year, a new borough map has been completed on a scale of 600 ft. to the inch, and the general work of the borough shows a substantial increase over last year.

The maps for 38 street opening proceedings have been completed, leaving about 133 still pending. Numerous other maps, such as change of grades and street lines have been compiled and adopted by the proper authorities.

Borough of the Bronx.

Forty-eight maps were submitted to the City authorities for adoption of street system and changes of the same. Twenty-five maps in triplicate of changes of street lines and grades were made for filing. Eight hundred and thirty monuments were set for establishing street lines. One hundred and sixty-eight proceedings are pending for acquiring title for streets and avenues within the borough. Thirty-two maps in quadruplicate and technical descriptions in triplicate, in 32 new proceedings were made and transmitted to the proper authorities.

Surveys were made for damage maps and profiles in 120 legal opening proceedings. 60 draft damage maps in triplicate were made. Final damage and benefit maps were made, comprising 960 sheets. 36 maps were adopted by the Board of Estimate and Apportionment, and approved by the Mayor, which were filed in the Office of the President of the Borough.

Borough of Richmond.

The primary traverses have been completed, and the plane table surveying has been materially extended. Concrete monuments are now being used in establishing secondary traverse stations. The most thickly settled portions of the borough have been mapped and reproductions by lithography made. The street system has been completed for a large portion of the mapped area. The following table gives a summary of the work completed:

Basic survey completed	36 480	acres
Topographic field details	20 000	"
Topographic mapped details	18 000	"
Street plans under study	7 000	"
Street plans ready for the Board of E. & A.	3 450	"
Street plans adopted by the Board of E. & A.	5 350	"

Borough of Queens.

The Borough of Queens has a land area of 67 174 acres, and a topographic survey has been made of 59 678 acres. Of this 49 694 acres have been compiled on an 80 ft. scale and 49 164 acres have been reduced to a 200 ft. scale.

The total acreage of maps of a tentative system of streets and grades adopted by the Board of Estimate and Apportionment is 17 916 acres. There have been transmitted to the Board of Estimate and Apportionment for its approval tentative maps of a combined area of 4 132 acres, and, in addition, tentative maps to the extent of 4 750 acres are nearly ready for approval by the same Board.

Thirty-three sections of the final maps, amounting to 8 895 acres, have been approved by the Board of Estimate and Apportionment. The field work connected with the preparation of these sections is entirely completed, all monuments having been set, accurately traversed and computed. Four sections containing 1 469 acres have been transmitted to the Board for its approval.

Fourteen sections of the final maps, containing 5 142 acres, are nearly completed and will be transmitted to the Board of Estimate and Apportionment early in 1910.

One hundred and nineteen proceedings for the legal opening of streets are pending, for which all the necessary maps have been completed. In a majority of these cases, however, all but the final maps have been furnished.

During the year, 832 monuments have been set to establish the lines of streets as shown upon final map sections. The old monument points in Long Island City, which have been replaced by new monuments, and the number of monuments re-set on account of the alterations to the established street system number 466.

In connection with the search of the old records for proof of the legal ownership of streets in this borough, the work of the past year has been mainly among the original papers and documents, obtained by the City from the various municipalities originally composing the present Borough of Queens.

These papers have never been systematically filed or indexed, as is now being done, and among them have been found many original deeds, and releases, the possession of which will obviate the necessity of expensive street opening proceedings. In one case during the past year, that of a street nearly a mile long, an opening proceeding was rendered unnecessary by information thus discovered, which saved the taxpayers many times the expense thus far incurred in this work.

The mass of records and papers to be gone over, both on account

of street titles and of improvement, is great, and the care necessary to insure accuracy renders the work slow of accomplishment, but the results obtained, and yet to be obtained, show it to be one of great value.

BUREAU OF HIGHWAYS.

Borough of Manhattan.

A contract of special importance to the City, executed during the year, was the widening of the roadway of Fifth Avenue, from Twenty-fifth Street to Forty-seventh Street, and to Forty-eighth Street on the west side. By this improvement the roadway of the Avenue is widened from 40 to 55 ft., thereby increasing its capacity nearly 50%. The encroachments which had existed, some of them to the extent of 15 ft. from the street line, have been taken down so that the sidewalk is at least 20 ft. wide, which is a greater width than was available before the roadway was widened.

Very little trouble, comparatively speaking, was encountered with the property owners along the line, although it inconvenienced them and put them to great expense in some cases. They all recognized the eventual benefits to the street and, accordingly, to the property.

The following is a list of the character and the amount of pavement laid in the borough:

Sheet asphalt	13.81	miles
Asphalt block	5.57	"
Granite block	3.82	"
Wood block	2.29	"
Total	25.49	"

Borough of Brooklyn.

During the year 37.26 miles of pavements were laid, including repaving and assessment work. The total mileage in the borough now being 714.14 miles, of which the asphalt pavement amounts to 382 miles. The cobble-stone pavements have been reduced to 18 miles; 54 miles of sidewalks were laid, at the standard width of 5 ft. in assessment contracts.

The average cost of sheet asphalt with a 5-in. concrete base, for the year shows a reduction of 24% from the preceding year, while

the average cost of granite pavement on a concrete base has increased 6% over the preceding year.

The amount of asphalt restorations carried on by the municipal asphalt plant shows a marked increase over last year's repair work. These costs compare well with the lowest maintenance contracts, considering all the elements of long haul, small patches and other contingencies in connection with the great advantage of having quick repairs made in emergencies.

In the summer of 1908 the Texas Company, without cost to the City, relaid the old sheet asphalt on Clinton Street, between Pierrepont and Fulton Streets, and two blocks of new asphalt on Nevins Street, on a foundation furnished by the City, and a block of bitulithic concrete on Eighteenth Avenue, mixed on the site of the work with rotating drums (details of which are explained in the President's annual address of 1908), all of which have been highly satisfactory, and competition has been allowed, through the success of the severe tests which this Company was called on to make before the Texas oil asphalts were accepted, with California oil asphalts and the natural product.

The maintenance work of the Bureau is assuming great proportions, there being about 2 900 000 sq. yd. of asphalt to take care of, which has cost during the past year about 3 cents per square yard; and 3 360 000 sq. yd. of block pavements, on which some 265 000 sq. yd. of repairs were made.

The difficulties of proper inspection are emphasized by the fact that corporation and plumbers' cuts to the number of 12 893 were made during the year. Two innovations in the street railway work have been introduced, which have allowed very great economy in construction; first, silicate of iron in competition with broken stone for concrete has been allowed, there being a large output of this material from the smelters of Newtown Creek, the cost of which has been between 50 and 60% of the cost of broken stone; and second, the use of split granite blocks laid and grouted in place in the railroad areas, allowing old granite blocks, generally known as specification blocks when nine inches or more in length, to be split, giving two new faces for blocks. The cost of this paving, as reported, has shown great economy as compared with new block work, and its durability and surface, with proper labor and inspection conditions are entirely satisfactory.

Borough of the Bronx.

About 8½ miles of street have been paved with a permanent pavement, making a total of 123 miles, and 13 miles of macadam pavement were laid, making a total of this class of pavement of 146 miles. Among the contracts completed during the year, were the Grand Boulevard and Concourses, at a cost of $1 050 000, and the transverse roads under the same charge at East One Hundred and Sixty-seventh Street and East Two Hundred and Fourth Street, at a cost of $225 000.

Number of contracts in force January 1, 1909..........	48
" " executed during the year..........	55
" " completed during the year........	51
" " in force December 1, 1909........	52
Estimated cost of the contracts let during the year 1909..	$1 700 000
Estimated cost of contracts in progress December 31, 1909.	2 055 000
Amount of work certified during the year..............	1 877 000

Borough of Queens.

Plans and specifications were prepared, contracts awarded and work completed for the following improvements: 0.08 miles of sheet asphalt, 2 miles of asphalt block, 0.44 miles of wood block, 3.12 miles of granite block, 5.76 miles of macadam with tarvia binder, 5.69 miles of concrete steel bound curb, 3.46 miles of bluestone curb, 1.6 miles of cement flag and 6.9 miles of bluestone flag. The total cost of the above improvements is $533 391.

The total amount of paved streets in the borough, and the character, is as follows:

Sheet asphalt	18.76	miles
Block asphalt	8.33	"
Wood block	5.51	"
Vitrified brick	9.58	"
Belgian block	4.53	"
Granite block	27.40	"
Macadam	348.63	"
Total	422.76	"

Borough of Richmond.

Contracts have been awarded aggregating about $450,000 for regulating, grading, paving and the construction of retaining walls at the St. George Ferry Approach, which are nearly completed. The following is a summary of the amount of pavement laid in the past year in the Borough:

Wood block	.25	mile
Iron slag	.14	"
Granite block	.43	"
Concrete pavement	.05	"
Macadam	.24	"
Vitrified brick gutters	9.12	"

Consistent daily reports and tabulations have been made throughout the year, concerning quantities, cost of road repairs and sewer operations. Two engineers and a stenographer have been kept engaged on this class of work.

BUREAU OF SEWERS.

Borough of Manhattan.

During the past year about 2 miles of sewers under the jurisdiction of this bureau have been completed, making in all about 522 miles of completed sewers, and 6 350 receiving basins have been built for the purpose of surface drainage.

This completed the sewer system within this borough as far as the street system has been laid out. There are considerable small tracts of land which are still undeveloped, and the work of laying out and building sewers on these tracts will be undertaken later on.

A serious question which is likely to be very much agitated in the near future is the adoption of some method of preventing the pollution of the river waters within the Greater City. The solution of this question is rendered very difficult from the fact that there are so many different commissions, corporations and civic bodies that have some measure of authority in the matter.

Borough of Brooklyn.

One hundred and seventy contracts were awarded for sewer improvements, estimated to cost $1 017 870. 15.92 miles of sewers

were completed, making a total at the close of the year of 838.67 miles, while 172 receiving basins were built, giving a present total of 10 285.

One of the most important sewer improvements, the Gowanus-Flushing Tunnel, is not yet in operation, although the tunnel has been completed for some time and contracts have been awarded for a screw pump and operating machinery, motor pit and station building, under three separate contracts. The total estimated cost of the tunnel ready for operation with such equipment is about $810 000.

As to the relief sewers of the borough, in which about half the appropriation of $2 000 000 was withdrawn by the Board of Estimate and Apportionment, Sections 1, 2, and 3 of the Gold Street sewer have been completed at a cost of about $850 000; but the full benefit of this relief of the Greene Avenue sewer, which is a 15-ft. trunk sewer, and its removal from the line of the four-track subway, now under construction in Fourth Avenue, cannot be had until the Greene Avenue sewer is relieved at Tompkins Avenue, which is an integral part of this relief-sewer plan.

The so-called interborough sewer in Scott and St. Nicholas Avenues is well advanced. The first section, at a cost of $312 197, being complete, while the second section has been held back by interference with the railroad crossing. It is about half completed.

Sections 1, 2 and 3 of the work on the East Ninty-eighth Street sewer are under contract, at an estimated cost of $270 000, while Section 4, leading to the disposal works, at an estimated cost of $100 000, has not been started owing to lack of title in the street to be occupied. Satisfactory arrangement for the temporary disposition of the flow has, however, been planned, so that the sections built may be put into use.

The tests of material of construction, including experiments on spray nozzles, and the knife-edge tests on sewer pipe, have given very satisfactory results. The cost-data records accumulated by the bureau have been somewhat improved upon, and cover, not only construction, but maintenance work as well.

Borough of the Bronx.

The total sewer improvements authorized by the Board of Estimate and Apportionment during the year 1909 were 17, at an

estimated cost of $325 063. During the year 1909, 12.4 miles of sewer and 253 receiving basins have been completed, making a total sewer mileage in the borough of 282 miles and 3 256 receiving basins.

On January 1, 1909, there were 16 contracts in force, at an estimated cost of $2 083 016. On December 31, 1909, there were 17 contracts in force, at an estimated cost of $1 980 577.

Thirty-nine contracts were completed, at a total cost of $1 016-369. Among these contracts were the Truxton Street sewer, from Leggett Avenue to the East River, and an outlet sewer in Avenue E (Pugsley Avenue). The work on the storm relief tunnel from Webster Avenue to the Harlem River has been pushed with great vigor, and is now completed sufficiently to be in use. The flow of the Webster Avenue sewer has been diverted into the same, and all that remains to be done on this contract is the general cleaning up and repairing of the surface conditions and the completing of a short portion of the sewer, paralleling the sewer in Webster Avenue up to the north line of Wendover Avenue.

Among the contracts let were the large outlet sewer in White Plains Avenue, from East One Hundred and Fifty-second Street to the East River, which will act as a permanent outlet for both the Avenue A and Avenue E sewers, and also the rebuilding of a portion of the outlet sewer in Hunts Point Road.

Borough of Queens.

The engineers of the bureau have made preliminary studies of sewers for about 3 000 acres of land, and have made final drainage maps to the extent of 2 500 acres. Numerous plans and profiles, with the necessary details of construction, have been prepared for contracts. The following construction work has been completed:

4.12	miles of sewers,
42	receiving basins,
159	manholes.
15 192	lin. ft. of house connections.

The contract cost of the above was $121 994.86.

Borough of Richmond.

Concrete and brick sewers completed......	1.45 miles
Pipe sewers completed....................	2.8 "

DIVISION OF SUBSTRUCTURES.

Borough of Brooklyn.

The Division of Substructures has made very substantial progress in surveying and mapping all the underground structures in the most congested section of the borough. The maps completed to date cover 35 miles of streets.

In this connection it is gratifying to note that the Commissioners of Accounts in their annual report devoted some space to the work of this division, stating that the bureau is of great value, and that the system be adopted in the several boroughs of the City.

BUREAU OF PUBLIC BUILDINGS AND OFFICES.

Borough of Brooklyn.

The preparation of the site of the 8th Ward Market, which the members of the Society visited during the year, is practically complete, except for a junction with a concrete wall of the Department of Docks, and the filling of the outer end of the site. About nine acres of land are now available for the market building designed for this improvement.

Important in the work of this bureau was the completion and opening of the Hamburg Avenue Bath and the President Street Bath, costing $188 754 and $170 060, respectively. Both of these buildings in interior arrangements and exterior design are very creditable.

Preliminary plans have been under way some time previous to a request of the Board of Alderman for a bathing pavilion at the ocean front of Coney Island, but no appropriation has been authorized for this work.

BUREAU OF BUILDINGS.

Borough of Manhattan.

Plans and specifications for 995 buildings at an estimated cost of $131 246 483 were examined during the past year, while plans for alterations were received and acted upon to the number of 3 578 at an estimated cost of $13 085 729.

Borough of Brooklyn.

Plans and specifications for 16 599 buildings, at an estimated cost of $61 081 367, were examined during the past year, showing an increase of 35% over the preceding year, while plans for alterations have been filed at an estimated cost of $4 387 556. The average cost of the buildings completed during the year was $5 693, showing a decrease of 21% in such average.

Borough of the Bronx.

Plans and specifications for 2 402 new buildings were examined and approved, the estimated cost of which amounted to $40 748 610. Plans for alterations of 654 buildings at an estimated cost of $966-655, were approved.

Borough of Queens.

Plans and specifications for 4 753 new buildings were received and approved, the buildings to cost approximately $19 407 900, showing an increase in the number of buildings and over 40% in the cost over the preceding year. The number of alterations were 1 082 and their estimated cost $780 934.

Borough of Richmond.

Plans and specifications for 729 buildings were examined and approved, the cost of said buildings being $2 367 276.

REFUSE DISPOSAL.

Borough of Richmond.

The street cleaning and refuse collection and disposal problems go hand in hand in this borough. The feasibility of disposing of City wastes by fire, has been demonstrated during the past year at the West New Brighton Refuse Destructor. This plant has been visited by engineers from all over the United States, and two of our largest western cities, Milwaukee and San Francisco, have adopted high temperature, mixed refuse incineration, such action having been based largely upon the experience and success in the operation of the Richmond Borough Plant.

DEPARTMENT OF PARKS,

Boroughs of Brooklyn and Queens.

During the past year, in Prospect Park, 10 700 evergreens and deciduous shrubs were set out, 130 000 sq. ft. of sods were laid, and the greater portions of the roadways and bridle paths were resurfaced with Hudson River gravel. The new tennis shelter house which is in course of construction will be ready for occupancy in the Spring.

A new shelter house has been constructed in the New Lots Park and was opened to the public during the year, and the new shelter house in Fulton Park is nearing completion.

The grading, fencing and laying out of the playground at White, Seigel and McKibben Streets is progressing, while the grading, paving and draining of the Ray Ridge Parkway between Fort Hamilton Avenue and Fourth Avenue is well under way.

The roadways of Ocean Parkway, Bay Parkway, Eastern Parkway, Forest Park, Highland Park and Shore Road were re-surfaced.

A new park containing about six acres, known as Highland Park, situated in the former Village of Jamaica, was acquired without any cost to the City and improved so that it can be used by the public.

Trees and shrubs were set out in Highland Park, Highland Boulevard, Eastern Parkway, Ocean Parkway and in various small parks.

Contracts for the paving of Parkside Avenue between Flatbush Avenue and the Park Circle, the Ocean Parkway Traffic Road between Eighteenth Avenue and Kings Highway, repairs to the three arch bridges and re-surfacing of the Speedway on Ocean Avenue are completed and bids for the work will soon be advertised.

The trees on City streets have been given thorough and systematic care; over 91 000 trees were sprayed, pruned or otherwise given attention.

Boroughs of Manhattan and Richmond.

The work of improving the small parks on Broadway between Fifty-ninth Street and One Hundred and Twenty-second Street (which were disturbed on account of the construction of the Broadway Subway), was prosecuted to completion, as far as regulating,

grading, resetting curb, depositing garden mold and paving with asphalt tiles is concerned; contracts are now in force and the work well under way, for erecting the ornamental railings, sodding and planting. This improvement may be considered one of the principal ones undertaken by the department during the year.

The work on the improvement of Chelsea Park was begun late in the Summer and will be completed in the Spring of 1910.

The unimproved territory between One Hundred and Twenty-second Street and Claremont Place, Riverside Drive and Claremont Avenue, known as the addition to Riverside Park was improved and converted into a park.

Tompkins Square and St. Nicholas Parks were enclosed with ornamental fences.

Temporary playgrounds were constructed in John Jay Park, at Cherry Street, at West Fifty-ninth Street and at East One Hundred and First Street.

Considerable improvements were made at Bridge "K," Central Park (East Drive, Ninety-seventh Street near Fifth Avenue). The line of drive was changed, and, through this improvement, the danger of accidents to pedestrians was considerably lessened. New walks were constructed and the roadway paved.

A contract has been awarded for laying out and improving Colonial Park between One Hundred and Forty-fifth Street and One Hundred and Fifty-first Street. Surveys and contract drawings have been prepared for improving John Jay Park, Riverside Slope, between One Hundred and Twentieth Street and One Hundred and Twenty-fourth Street, Conservatory Lake, and for the taking down, rebuilding and repairing of the Battery Sea-wall.

Borough of The Bronx.

In Bronx Park the boundary and partition fences around the elephant yards, the wall and fence on the easterly extension of the park, which was commenced in 1908, has been completed. The administration building at the Zoological Park which was started in 1908, will be completed about January 10th, 1910. A new comfort station and storehouse is in course of erection and is well under way.

In Pelham Bay Park the hexagonal asphalt block pavement on

the Parkway from Bartow Station to City Island, which was commenced in 1908 has been completed.

At Van Cortlandt Park the work of laying the water pipe for irrigating purposes and the resurfacing of the north end of Rockwood Drive, including a part of Vault Hill Road, has been completed, while the extensive Colonial Garden Improvement, which was started in 1905, is still under way.

The work of laying water pipes through Crotona Park for irrigating purposes has been completed and 2 500 ft. of gutters along the roads have been laid.

A large amount of filling necessary in the low land contiguous to Cromwell's Creek, in McComb's Dam Park, was completed by the New York Central and Hudson River Railroad, while the filling in of the low lands adjacent to Robins Avenue is well under way. At the Claremont Park, the improvement along Clay Avenue has been completed, and also the laying of water pipes for irrigating purposes and the planting of trees, while the construction of fireproof vaults in the office building is progressing.

St. Mary's Park has been enclosed by a wrought-iron fence and the grounds filled in, and the northwesterly section of the park has been graded, seeded and planted with shrubs. A large amount of water pipe has been laid for irrigating purposes. Two flights of granite steps and the asphalting of the walks are now under way.

The wall on the northerly side of St. James Park and the foundation wall on Creston Avenue, which was begun in 1907, has been completed.

The bridle path along the south side of the Spuyten Duyvil Parkway, including a large amount of gutters, has been completed. Considerable filling was done in the park and the railing on the wall near the western terminus was completed.

On Mosholu Parkway, improvements were made to the glen near Webster Avenue, including 2 000 ft. of walk laid and the planting of 4 100 evergreens and deciduous shrubs. During the Summer the roadway was sprinkled with 20 000 gal. of asphaltic road oil. Work is now progressing on the granite steps from Webster Avenue to the bridge.

During the year a new roadway was built about two miles long, along the Southern Driveway, and 2 000 lin. ft. of gutters were con-

structed. The road from Williamsbridge to the Westchester Road was reconstructed.

This attempt to cover the main features of importance and interest in connection with the engineering problems of the City in a single address has enabled me to do little more than mention them. I regret that time and space will not permit me to give in full the many admirable papers furnished me by the Engineers of the City, and the public service corporations, to whom I am very much indebted for courtesies shown in supplying the data contained in this paper.

ANNUAL DINNER

The Seventh Annual Dinner of the Society was held at the Hotel Savoy, Fifty-ninth Street and Fifth Avenue, on January 11th, 1910. There were present 390 members and guests.

The President, Mr. Robert R. Crowell, acted as Toastmaster and introduced the speakers of the evening, who were Hon. George Cromwell, President of the Borough of Richmond; Hon. Silas C. Miller, President of the Borough of The Bronx; Mr. John F. O'Rourke, Prof. Edward W. Bemis, Deputy Commissioner of the Department of Water Supply, Gas and Electricity, Borough of Manhattan; Mr. John C. Wait and Mr. Merritt H. Smith, Department Engineer, Board of Water Supply.

During the evening several popular songs were sung, and Mr. Fred. George, of the Topographical Bureau, Borough of Queens, entertained the diners with a vocal selection which was very much appreciated.

Address of President Robert R. Crowell.

Brother Members of the Municipal Engineers, and Guests:

It is with a feeling of gratification and admiration that I view the ever-increasing membership of this Society. Each succeeding dinner brings new faces and an increased enthusiasm, and as the Society increases in membership it increases its influence for good government, which acts for the credit and benefit of the City of New York and its engineers.

In looking backward seven years to the time when this Society was organized, we find that the municipal engineers of the City were practically unknown, not only to the public, but among themselves. Engineers in one Department were unacquainted with those of another Department, both under the same executive head. Engineers in charge of Departments in one borough were unacquainted with those in other boroughs. Under these conditions, it can readily be seen how some specific work would be done several times by various Departments for different improvements. This in itself was costly to the City and certainly was not conducive to good feeling among the employees of the different Departments. If

there was one thing that a man liked to do, it was to differ from another and then prove that he was right. Since the organization of this Society these conditions have all changed, brought about by the social relations which are encouraged and maintained at our meetings. Here one meets the engineer and learns to know him as he is, not as some poor artist has sketched him. If the engineer of any Department within the City desires any information of a public character from another borough, he has no compunction in asking the engineer of that other borough to furnish it, and in every case, if it is available, it is furnished to him. A feeling of good fellowship permeates this Society and has broadened the views of its members, and it is one hope and desire that its membership may increase and that every eligible engineer in the employ of the City of New York may become a member in the very near future.

Hon. George Cromwell, President of the Borough of Richmond, responded to a toast on "The Golden Gate," which he claimed was the Borough of Richmond. He made many interesting comparisons between this "Golden Gate" and the other boroughs, and called attention to the great importance of the Borough of Richmond as a place for the homes of the thousands who daily labor in the crowded Borough of Manhattan and elsewhere.

He also said that long ago Richmond had learned one thing, and that was, that the only way to plan a structure was to get the best advice and the best talent to advise you that could possibly be obtained, and he had found that the best advice was that of the engineers. To this policy he laid, to a great extent, the success of the Borough of Richmond.

Hon. Silas C. Miller, President of the Borough of The Bronx, responded to a toast on "The City's Future." He endeavored to show that the City's future meant the Borough of The Bronx, but confessed that he feared a strong rival in the Borough of Kings. He paid great tribute to the work of the engineers as the real creators of the great structures and public improvements, and congratulated the City that it had such a society as the Municipal

Engineers, which could be depended upon to make the City of New York the pride of the country and of the world.

MR. JOHN F. O'ROURKE, in response to a toast on "The Evolution of the Engineer," told the Society how the profession of engineering had advanced from the early days when the City Surveyor was the greatest engineer in existence, up to the present time, when an association like the Municipal Engineers was possible. He spoke of the gradual advancement of the influence of the engineer in directing the policy of business affairs of great enterprise, stating that the day of the lawyer and the business man in municipal government was rapidly drawing to a close, and cited the Pennsylvania Railroad as an example of a corporation in which all of the executive officers came through the engineering corps.

He characterized the engineer as a man who was trained in science, in mathematics and in general business, and called attention to the fact that "general business" was nothing more than "giving the other fellow what he wanted and getting something out of it for yourself."

In glowing terms he referred to the City of New York as the greatest city in the world, and the reason therefor was not because it was created for that purpose by the Almighty, but because its municipal engineers had made it possible.

PROF. EDWARD W. BEMIS, Deputy Commissioner of Water Supply, Gas and Electricity, responded to an invitation from the President as follows:

Mr. President and Friends:

This is quite a surprise to me to-night. I am delighted to be here and to be asked to say a few words. It certainly is too bad that Commissioner Thompson could not be here to fill his place on the program, but I happen to know that he was detained at his office until late to-night with one of the prominent engineers of the city in consultation upon the work of the Department.

This is a unique Society, this Society of Municipal Engineers. Probably there are not more than one or two others like it in this

country, and none so large. I doubt if there is more than one or two others in any part of the continent, and such a Society would not have been possible a few years ago, even in New York. It is also a unique occasion. You are here to-night after a great political battle. You are here, as I learn, able to show a most astounding fact; a fact that could not be, I think, anywhere else on this continent, viz., that out of the Society, which numbers 600 men, not a dozen have lost their places for political reasons on account of the change in administration. Not one-fiftieth of your membership has thus lost work with the City on account of the change, and when you have seen how the scythe has mowed down Borough Presidents and Commissioners, Deputies and others, you can feel that the prayer of the private as he was going into battle has been fulfilled. When he was asked what he was praying for, he said that he was praying to the Lord that the bullets, like the pay, might go chiefly to the higher officers. On that point we are beginning to appreciate the fact that although your tenure is liable to be more secure than formerly, the pay is not yet what it should be. It is a fact that throughout the country those carrying out the higher engineering and other administrative details of the City and National Government are not receiving pay commensurate with their work, or such as private parties give. Yet, on the whole, I think that it is a unique situation and one which we, as citizens of New York, can well be proud of, that the engineering profession is coming to be so well recognized in municipal work.

We have been told to-night of the importance of the Engineer in municipal work, and I am sure no one has a higher regard for it than I have. Formerly it was thought that the improvement of our cities would come chiefly through eradicating one evil which was seen to be widespread and which is not yet fully eradicated, but is being seriously attacked, viz., the spoils system in the ordinary work of clerical and labor departments of the City, but of late it is being recognized that this is only one of the problems which must be solved before we get proper City government. We are waking up fast to the engineering problems. We are recognizing that good engineering is vital and that it must be secured, as well as the abolition of the "Spoils System," but it is well to be also a little modest, I think, and to recognize that there are also two other

phases of City work which have their place and are coming more and more into the public eye: One is accounting, cost keeping and the whole question of a proper organization of the accounts; another is the financing of the City, the raising of the funds, the providing for the engineer a fee. I might add even another department of City works, which might be called general, executive or administrative work, and which should always go hand in glove with the engineer. With a proper organization and recognition of this work, we can work together hand in hand to make the administration of the next four years one which will not only be to the engineer the field which he needs, but which will give to the City an opportunity to be a model to the entire United States in everything that pertains to civilization in the line of government and administrative efficiency.

MR. JOHN C. WAIT, upon request of the Toastmaster, spoke of the desirability of an engineering education for those who follow the legal profession, and also for the encouragement of the artistic in engineering; and stated that the engineer, more than the Mayor, the Board of Estimate, or any other body, was fast becoming the real power in the decision of questions of policy and action in regard to the spending of the City's money for works of improvement.

MR. MERRITT H. SMITH, Department Engineer, Board of Water Supply, after one of his usual entertaining stories, congratulated the City of New York on its progress and prosperity, stating that such success had only been made possible by the work of its engineers, and that the City of New York was what the members of this Society had made it.

QUEENSBOROUGH BRIDGE,

INSPECTED BY THE SOCIETY, MARCH 27TH, 1909.

This bridge was inspected by over 100 members of the Society. It extends from Fifty-ninth Street and Second Avenue, Borough of Manhattan, to Jane Street and Jackson Avenue, Borough of Queens. It is of the cantilever type, about 7 424 ft. in length, including the Manhattan and Queens approaches, which are respectively 1 069 and 2 630 ft. long.

The main dimensions are as follows:

Length of bridge proper	3 724½	ft.
" " river span, west of island	1 182	ft.*
" " " " east " "	984	"
" " island span	630	"
Clear height above mean high water	135	"
Width between railings of lower floor	86	"
" " " " upper "	67	"
Distance center to center of trusses	60	"
Height of towers above bottom chord	185	"
" " trusses at anchor piers	48	"
" " trusses in center of river spans	45	"
Longest sub-panel of trusses	40	"
Shortest " " "	20½	"
Maximum grade on bridge	3.41%	

The capacity and loading of the bridge is as follows:

Upper Floor.	Live Load, in lb. per lin. ft. of bridge
4 El. R. R. tracks, at 1 700 lb. per lin. ft.	6 800
2 Promenades 11 ft. wide, at 75 lb. per sq. ft.	1 600
Lower Floor.	
2 Outside trolley tracks, at 1 000 lb. per lin. ft.	2 000
2 Inside trolley tracks, at 1 000 lb. per lin. ft.	2 000
1 Roadway, 36 ft. wide, at 100 lb. per sq. ft.	3 600
Total maximum live load	16 000

* This is the fourth longest span in the world, and is only exceeded in length by the Brooklyn Bridge, 1 595 ft., the Williamsburg Bridge, 1 600 ft., and the Firth of Forth Bridge, 1 710 ft.

This weight of 16 000 lb. per ft. over entire bridge is equivalent to the following loading:

250 Rapid transit cars carrying......	30 000	people
300 Trolley cars carrying............	30 000	"
Congested traffic on promenade.......	55 000	"
" " " roadway	100 000	"
	215 000	people

or about 100 lb. per sq. ft. over entire area of upper and lower floors.

The approximate total dead load, including track material, paving, etc., equals 120 000 000 lb., or 32 200 lb. per lin. ft. of bridge.

For the present, no elevated railroad tracks will be used. When they are required, the promenades will be placed on outside brackets of the upper floor.

There are 11 expansion joints, 7 of which allow for a 5½-in. expansion, 2 for 1½-in., 1 for 14-in. and 1 for 18-in.

Forty-six men lost their lives during its construction.

The approximate cost is as follows:

Land	$4 400 000
Masonry work, including steel in approaches	5 000 000
Steel superstructure, main span..........	7 600 000
Total	$17 000 000

The work was done under the authority of the Department of Bridges of the City of New York, Mr. Kingsley L. Martin, Chief Engineer, and Mr. John A. Knighton, M. M. E. N. Y., Engineer in charge.

PROPOSED EIGHTH WARD MARKET IN BROOKLYN.

INSPECTED BY THE SOCIETY, MAY 1ST, 1909.

This excursion was to inspect the site of this proposed market, and to see the work necessary to prepare this site for the erection of the buildings thereon. This property is situated just north of

the Brooklyn terminal of the Thirty-ninth Street Ferry, is owned by the City, and covers an area of 15.73 acres, of which 13.73 acres are under water. Over this inundated area the water averages about 4 ft. in depth at mean low water, necessitating filling in and bulkheading practically the entire site. A concrete bulkhead wall on a crib-work foundation of a total length of 1 750 lin. ft. was constructed. The concrete wall averages 11 ft. in height, is 4 ft. wide at the top and 5 ft. at the bottom. The concrete is composed of one part cement, two parts sand and five parts broken trap rock. The weight of the wall is about 7 530 lb. per lin. ft. The crib foundation is 20 ft. wide at the top, 32 ft. wide at the bottom and averages 24 ft. in depth below mean low water. The back of the crib is carried up to within 4 ft. of the top of the concrete face wall at the rear of the same. Upon the completion of the work a depth of 18 ft. at mean low water will be provided in front of the structure.

To construct and sink the crib work it was necessary to excavate a trench of ample width, and it was found upon investigation that the material to be excavated was entirely suitable for filling, being composed of sand.

One of the novel features of this work was the use of a hydraulic dredge in place of a dipper dredge in excavating the trenches, and at the same time utilization was made of the dredged material for filling back of the temporary bulkhead previously construted within the area to be enclosed. Upwards of 100 000 cu. yd. of filling were thus deposited, which, with the other selected material dumped by contractors' wagons and others free of cost to the city has resulted in redeeming about 9 acres of land.

The cost of dredging and depositing in place about 100 000 cu. yd. of material was 22 cts. per cu. yd. If a dipper dredge had been used the dredging alone would have cost at least 45 cts. per cu. yd., and the material would have been wasted by dumping at sea. The method adopted resulted in a saving of upwards of $40 000.

The crib was sunk in sections of about 300 ft. in length, tied together in the usual manner and held securely in position by piling driven through the crib pockets at the ends of the abutting sections, using in each case 14 piles for the purpose. The crib was

compactly loaded with rip-rap and sunk in the usual manner. The concrete bulkhead wall was built in alternate sections 16 ft. ir length, and the settlement closely watched and provided for in such a manner that the finished work presented an excellent alignment.

In constructing this bulkhead provision was made for the future construction of a transfer bridge and 2 piers. The preparation of the site is about completed, and the city now possesses a valuable piece of waterfront property upon which it is proposed, in the near future, if sufficient funds become available, to start the construction of the market buildings, plans for which have been prepared by the Bureau of Public Builings and Offices of the Borough of Brooklyn, which bureau has had entire charge of this work.

EDISON PORTLAND CEMENT MILLS AT NEW VILLAGE, N. J.

INSPECTED BY THE SOCIETY, JUNE 5TH, 1909.

Two hundred and six members attended this excursion to New Village, N. J., which is about 70 miles from New York. This plant is situated on the same geological formations and is using the same rock as is used in the Lehigh Valley Portland cements. They make and ship from 6 000 to 8 000 bbls. of Portland cement daily, and guarantee every barrel of it to pass all standard specifications.

The plant is unique in many respects, it having been designed, built and operated by Thomas A. Edison, whose name it bears.

In the quarry, Keystone Artesian Well Drills are used instead of steam or air drills, and those who witnessed their working can attest to their economy. Steam shovels are used for loading, thereby greatly reducing the cost of the stone.

Instead of jaw crushers or gyratory crushers for preparing the rock, Edison giant rolls are used. The largest of these is capable of taking a single stone weighing from 6 to 8 tons and reducing it to 6-in. pieces in from 15 to 20 seconds. An exhibition of this

during the visit of the Society was the marvel of all present. From the giant rolls the rock passes to 3 sets of smaller rolls, which reduce it to ½-in. pieces or less. It is then dried and placed in storage bins of sufficient size to hold a week's supply, it being automatically sampled any minute on its way to the storehouse. The ample storage capacity gives the chemists time to get complete analyses and figure their mixtures to a pound. Moreover, after carefully determining what proportions their mixture should be, they carry it out in practice just as accurately. Instead of making proportions by a given number of wheelbarrows or small cars of each kind, everything is weighed by an ingenious system of scales so arranged by electrical installation that the instant the scale beam tips, the electrical connection is broken and the feed stopped. While there is an attendant at all times, it is impossible for him to overweigh either by accident or design. The secret of uniform cement is to have a uniform mixture of raw materials, and with the system for accomplishing this in the mill and a large staff of chemists to regulate it, they should never go astray on quality.

After the accurate proportions are obtained the materials go through 4 sets of fine grinding rolls and a system of air separation, whereby they are all ground so fine that 82 per cent. of it passes a 200-mesh sieve. It is then ready for burning, which is accomplished in 10-rotary kilns, each 7½ ft. in diameter and 150 ft. long, these being the longest in existence. Mr. Edison is the originator of the long kiln, and since his has proven successful other companies are following suit, there now being a great number of them, although not quite so long, in use in other mills.

To those who have never seen pulverized coal used successfully, a trip to a modern Portland cement mill would be well worthy of the time and expense involved.

After the cement is burned, it is necessary to regrind it, and the clinker-grinding department is in every respect similar to the raw material department. Five sets of rolls and a blower system reduce the cement so fine that 85 per cent. of it passes a 200-mesh sieve, which is 10 per cent. greater than required by the standard specifications. There are 3 separate cement stock houses with a total capacity of 550 000 bbls., and 3 packing houses of

about 20 000 bbls. daily shipping capacity. The plant is motor-driven throughout, and has many labor-saving devices.

STORM RELIEF TUNNEL SEWER IN THE BOROUGH OF THE BRONX.

INSPECTED BY THE SOCIETY, JUNE 26TH, 1909.

Over 125 members of the Society and friends attended this inspection. This work is intended to relieve the Webster Avenue sewer, which in times of flood has been found to overflow and cause much trouble and damage to property in its vicinity. The existing sewer is tapped at the corner of Webster and Wendover Avenues, from which point the new conduit runs westerly, mostly in tunnel, to the Harlem River, into which it empties a short distance north of Highbridge, at an elevation of 6 ft. below mean high water. It has a total length of 6 896 ft., of which 1 164 ft. is open cut, 3 481 ft. in rock tunnel and 2 251 ft. in timbered tunnel. It will drain 1 500 acres, has a capacity of 1 350 cu. ft. per second, and will cost about $800 000. The excavation within the maximum lines amounts to 8 cu. yd. per lin. ft. of tunnel. The amount of roof over the tunnel varies greatly, the maximum depth of flow line from surface of ground being 152 ft.

The principal places of interest at the time of the visit were at and near the Harlem River, where it was found necessary to reduce the height and change the form from a single to a twin sewer where it passed under the 13 tracks of the New York Central and Hudson River Railroad, and which required extra careful piling and very heavy structural steel and concrete work, and west of the Morris Avenue shaft in timbered tunnel, where reinforced concrete construction was in progress.

The principal estimated quantities are:

Excavation of all kinds............	88 000	cu. yd.
Class "A" concrete................	5 700	" "
" "B" "	600	" "
" "D" "	13 700	" "
Reinforced steel bars.............	230	tons
Structural steel	190	"
Timber (ft. B. M.)................	1 000 000	ft. B.M.

This work was described in detail in the *Engineering Record* of March 2, 1907, and December 4, 1909.

The sewer was designed in the office and is being constructed under the general supervision of Mr. Josiah A. Briggs, M. M. E. N. Y., Chief Engineer of the Borough of The Bronx, by the Bureau of Sewers, Mr. Charles H. Graham, Engineer in charge; Mr. Josiah H. Fitch, M. M. E. N. Y., Principal Assistant Engineer, and Mr. G. L. Christian, M. M. E. N. Y., Assistant Engineer in charge of construction.

Messrs. McDonald and Barry are the contractors.

ST. GEORGE RETAINING WALL.

INSPECTED BY THE SOCIETY, OCTOBER 23D, 1909.

This work is adjacent to the Municipal Ferry Terminal at St. George. Its construction was necessitated by the widening and extension of Jay Street, Stuyvesant Place and South Street, to afford proper facilities for traffic and to reduce the grade of the street leading to the ferry. The wall is of a reinforced concrete type with a heavy base, having a width of one-half the height and connected to the wall proper by counterfords, spaced 8 ft. apart on centers.

A detailed description of the construction of this wall was given in a paper read before this Society by Mr. L. L. Tribus, Consulting Engineer and Commissioner of Public Works of the Borough of Richmond in December, 1908, and also in articles published in the *Municipal Journal* of January 13, 1909, and in the *Engineering Record* of July 11, 1908.

The total length of the wall when completed will be about 4 400 ft. and it will have a maximum height of 45 ft.

The principal quantities are as follows:

Concrete	20 700	cu. yd.
Steel	1 050	tons
Excavation	46 000	cu. yd.
Granite facing	7 910	sq. ft.
Granite coping	3 910	lin. ft.
Piling	30 000	" "
Total approximate cost	$470 000	

The work is being done under the direction of Mr. L. L. Tribus, M. M. E. N. Y., Consulting Engineer and Commissioner of Public Works, and Mr. Theo. S. Oxholm, M. M. E. N. Y., Engineer-in-Charge of the Bureau of Engineering-Construction of the Borough of Richmond. Mr. Geo. Wood is Resident Engineer in direct charge of the work.

REFUSE DESTRUCTOR AT WEST NEW BRIGHTON, S. I.

INSPECTED BY THE SOCIETY, OCTOBER 23D, 1909.

This plant destroyes all household refuse, such as garbage, ashes, rubbish, etc., from one of the districts of Richmond Borough. It has been in successful operation for about 18 months without causing a single complaint of nuisance from the adjoining householders. Mixed refuse is burned at a high temperature with a properly controlled air supply, resulting in a complete combustion of the gases, thus obviating the usual obnoxious odors from the inperfect burning of garbage. The by-products are steam and clinker or slag. A 180-h. p. boiler is connected with the furnace and the high temperature gases pass through the boiler and an air heater after leaving the furnace and before entering the chimney. The steam raised is used about the destructor, and a 50-k. w. generator was being installed at the time of this visit. Clinker is used as an aggregate in making concrete for various municipal purposes.

The foundations, building, runway and chimney of the plant are built entirely of reinforced concrete. This destructor has demonstrated the feasibility of burning the mixed refuse of Richmond Borough in a sanitary and economical manner within the district from which the refuse is contributed, to the entire satisfaction of the citizens and officials concerned. It presents an interesting example of engineering skill applied to a difficult and rather troublesome municipal problem.

The different features of the plant were explained to the visitors by Mr. John T. Fetherston, M. M. E. N. Y., who designed the refuse destructor, and under whose direction it was erected.

ASHOKAN RESERVOIR.

INSPECTED BY THE SOCIETY, NOVEMBER 6TH, 1909.

Perhaps the most successful excursion of the year was made to this most interesting work. About 215 members of the Society attended this excursion, going by a special train of six coaches and three dining cars over the West Shore Railroad, and the D. & H. R. R. to Brown's Station, N. Y., in the Catskill Mountains.

The Ashokan reservoir is situated in the Esopus Valley, and will have an available capacity of 127 000 mil. gal. It is formed by a system of dams and dikes having a total length of about 5½ miles, the principal one of which is the Olive Bridge dam. The total length of this dam measured along the crest is 4 620 ft., of which the central portion is of cyclopean masonry, 1 000 ft. long, rising 210 ft. above the bed of Esopus Creek, and having a maximum thickness of 200 ft. The balance of the dam consists of two earth wings with a maximum thickness of 800 ft.

An impervious foundation for the masonery portion was prepared by stripping about 10 ft. of rock, excavating with channelers a cut-off trench across the entire creek bed, and then drilling holes through which grout was forced under pressure to fill crevices in the rock. In order to keep this trench free from water while masonry was being placed, a system of pipes was laid from the water-bearing seams to a main pump. Through these pipes the seams tapped were similarly filled with grout, forced in under pressure after the masonry had sufficiently set.

To prevent temperature cracks in the masonry portion of the dam, it will be divided into sections 84 ft. long by transverse vertical expansions joints with vertical faces of concrete. These joints are tongued and grooved to avoid a continuous open crack through the dam when the latter contracts. A vertical inspection and drainage well at each expansion joint will afford opportunity for studying conditions there. Between these joints, about every 12 ft., drainage wells 16 in. in diameter, of large, hollow porous-concrete blocks, are provided to intercept any seepage into the masonry.

Small quantities of water which may enter the body of the

dam, either by the expansion joints into the inspection wells or through capillary spaces in the masonry, will be conducted by means of the wells to a longitudinal inspection gallery in the lower portion of the dam. This gallery opens into a transverse one leading to the down-stream side of the dam. A longitudinal gallery connects the tops of the wells.

After the completion of the dam the inspection wells may be filled with material that will effectively stop all flow. During construction, the stream-flow will pass through an opening in the dam, 35 ft. wide and 40 ft. high.

For a month previous to this inspection, the masonry construction in this dam had progressed at an average of over 1 000 cu. yd. per day.

The estimated cost of the whole work is $12 669 775; the main approximate quantities being as follows:

Earth excavation	2 055 000	cu. yd.
Rock "	425 000	" "
Embankment and refilling.........	7 200 000	" "
Masonry, all classes...............	874 000	" "
Rubble, paving and rip-rap........	105 000	" "
Portland cement....................	1 100 000	bbls.

The work is being done by the Board of Water Supply of the City of New York, under the supervision of Mr. J. Waldo Smith, M. M. E. N. Y., Chief Engineer, and Mr. Carleton E. Davis, M. M. E. N. Y., Department Engineer; MacArthur Brothers Company and Winston & Co., are the contractors.

PENNSYLVANIA RAILROAD TERMINAL STATION.

INSPECTED BY THE SOCIETY, NOVEMBER 27TH, 1909.

Through the courtesy of Mr. George Gibbs, Chief Engineer Pennsylvania Tunnel and Terminal Railroad, over two hundred members of the Society made a most profitable and interesting inspection of this station, on the west side of Seventh Avenue, between Thirty-first Street and Thirty-third Street on November 27, 1909.

In a work of such magnitude it would be useless, in an article of this length, to attempt anything more than to note some of the main features, and enumerate some of the principal quantities entering into its construction.

1. Passenger Station Building—784 ft. long, 430 ft. wide; average height above street, 69 ft.; maximum height above street, 153 ft.; main waiting room, 277 ft. long, 103 ft. wide, 150 ft. high; concourse, 340 ft. long, 210 ft. wide.
2. Area of station building at track level, 7.74 acres.
3. Total trackage, 16 miles.
4. Number of standing tracks at station, 21.
5. Highest point of tracks below sea level (M.H.W.), 9 ft.
6. Number of passenger platforms, 11.
7. Length of platforms adjacent to passenger trains, 21 500 ft.
8. Number of baggage and express elevators, 25.
9. Length of baggage, express, trucking and pipe subways, 5 200 ft.
10. Number of electric lights, in terms of 16-c. p. lamps and enclosed arc lamps in passenger station building, 532; incandescent, 21 951; total, about 30 000.
11. Number of columns supporting station building, 650.
12. Greatest weight on one column, 1 658 tons.
13. Weight of station building steel, 27 500 tons.
14. Area of station and yard (Tenth Avenue to normal tunnel section, east of Seventh Avenue), 28 acres.
15. Number of buildings removed on station and yard area, 500.
16. Storage capacity of station yard tracks, 386 cars.
17. Total excavation required, 3 000 000 cu. yds.
18. Length of retaining walls, 7 800 ft.
19. Length of streets and avenues carried on bridging, 4 400 lin. ft., or an area of about 8 acres.
20. Weight of street bridging steel, 24 000 tons.
21. Loading per square foot on avenue bridging, $1\frac{3}{4}$ tons.
22. Maximum loading per square foot on bridging east of Seventh Avenue, 5 tons.
23. Concrete required for retaining walls, foundations, street bridging and sub-structures, 160 000 cu. yds.

24. Proposed initial daily service of P. R. R. trains, 400; proposed initial daily service of L. I. R. R. trains 600; total, 1 000 trains.
25. Dimensions service power plant on Thirty-first Street, 160 ft. by 100 ft.
26. Boiler capacity of service power plant (ultimate), 5 000 h. p.
27. Weight of steel in service building, 2 437 tons.
28. Power and light generators in service building, 2 000 k. w.
29. Air compressors, 2 of 2 000 cu. ft. per min., 2 of 200 cu. ft. per min.; total, 4 400 cu. ft. per min.
30. Hydraulic pumps, 2 of 1 500 gal. per min., 1 of 500 gal. per min; total, 3 500 gal. per min.
31. Refrigerating machines, 2 of 40 tons per day, 1 of 3 tons per day; total, 83 tons per day.
32. Coal handling plant, capacity per hour, 100 tons.
33. Ash handling plant, capacity per hour, 50 tons.
34. Station heating plant, B. T. U. per hour, 85 000 000.
35. Traction substation capacity, 6 000 k. w.

The architect on the Terminal is Mr. George Rea.

JOHN ALEXANDER DUNTZ.

MEMOIRS OF DECEASED MEMBERS.

JOHN ALEXANDER DUNTZE.

John Alexander Duntze was associated with municipal work for about a quarter of a century. He was originally appointed a draftsman in the Department of Docks on July 29th, 1885, which position he held until January 12th, 1900, when he was promoted to assistant engineer, the position he occupied at the time of his death, which occurred on October 24th, 1909. His last appearance on the work was on October 7th, 1909, when he was afflicted with paralysis of the heart.

He was born in England in 1855, receiving his education at Eton, and afterwards studying engineering at Sandhurst College. He was a member of the Royal British Engineers Society, and was next in line for the baronetcy of Sir George Alexander Duntze, Baronet, who was his first cousin. He was also a relative of Alexander Cockburn, at one time Lord Chief Justice of England. His father, the late Admiral John Duntze, was the first man in the British Navy to take a battleship through the Straits of Magellan.

Mr. Duntze left a widow, two sons and a daughter.

HENRY H. BITTMAN.

Henry H. Bittman was born in New York City on the 25th day of February, 1855. His early education was received in the public schools of New York City. In the year 1872, he enrolled as a regular student at Cooper Union, in the scientific course. Having completed his studies at Cooper Union in 1877, he received the Cooper medal and the degree of Bachelor of Science. He was one of the founders of the Cooper Union Alumni Association.

He was engaged in the architectural profession up to 1899, when he entered the service of the City of New York. He was appointed a topographical draftsman by the Board of Public Improvements and assigned to the Topographical Bureau of the Borough

of The Bronx. While in this bureau he worked on the map of Greater New York City, made for the Paris Exposition, and for which he received a certificate of honorable mention from the Paris Commission. In 1900 he was assigned to the Brooklyn office under the same title. In 1902 he was appointed a topographical draftsman in the Topographical Bureau of the Borough of Queens, and remained there until his death, which occurred after a short illness, on the 2d day of February, 1909.

JAMES H. RICHES.

James H. Riches, a charter member of the Municipal Engineers, was born on March 20th, 1846, at Loughgall, County Armagh, Ireland. His elementary education was received at the local academy, the study of engineering being taken up later in life in England. In 1870, at the age of twenty-four, he came to this country and joined the engineering staff of the New York Central Railroad. The principal work he did while with this company was a survey of the Mohawk Valley Railroad, and the building of the Fourth Avenue railroad bridge across the Harlem River.

In October, 1879, he resigned from the railroad company and entered the service of the City of New York in the Department of Public Works. In 1879-1880, he was the City Inspector on the construction of the New York Central and Hudson River Railroad Company's tunnel under Park Avenue, and in 1881 and 1882, on the preliminary surveys and investigations connected with the location of the Quaker Bridge Dam. From 1882 to 1884, he was associated with Mr. Samuel L. Cooper in running check levels and establishing bench marks along the Old Croton Aqueduct from Croton Dam to High Bridge, and in locating and surveying the line of the New Croton Aqueduct, from the south line of the City of Yonkers to the 135th Street gate-house, including all of the property surveys within said territory.

From 1884 to 1898 he was in charge of the surveys of the contours of the Croton Valley from Croton to Croton Falls, N. Y., and also made surveys of all the farm lines within one-quarter of a mile of the 206-ft. contour of the whole water-shed tributary to the lake, formed by the New Croton Dam.

JAMES H. RICHES.

HENRY H. BITMAN.

From this time until 1901, with the Department of Water Supply, Gas and Electricity, he had charge of surveys and construction of several of the smaller dams on the Croton water-shed, tributary to the present system of water supply. During all these years his work was of uniform high quality and his superior officers placed absolute confidence in his reports. He was a strict disciplinarian, but always retained the respect and good will of his subordinates, and those who worked under him considered themselves fortunate. One of his habits was to compute all of the day's work each evening and plot the same, so that any errors in field notes might be discovered when the work was fresh in the minds of all in the party, and these notes, when turned in at the main office, were invariably found to be correct.

In 1902 he was appointed Assistant Engineer in the office of the President of the Borough of Richmond, and for five years had immediate charge of all the work of paving the streets of that Borough. In 1907, at the personal request of his old friend, John W. McKay, Assistant Engineer in the Department of Water Supply, Gas and Electricity, he accepted a transfer to that Department, where he worked until the Spring of 1909, when he obtained a leave of absence for several months in order to make an extended European tour. He had been heard to make the remark that he wished to do this before he died. During the seven years he worked in the Borough of Richmond he acquired and held the friendship of all who came in contact with him, and on leaving the office of the Borough President a complimentary dinner was tendered to him.

While employed in the reservoir work on the Croton water-shed, be married Mrs. Horton (*née* Brown), on October 13, 1890, at Peekskill, N. Y., and moved to Staten Island in 1902, purchasing a handsome home on Dongan Street, West New Brighton. The sudden death of his wife in April, 1904, was a great shock to him, and it is doubtful if he ever recovered from it. After having completed a three months' tour of Europe and when about to sail for home, he was attacked by a fatal illness while visiting his sister at Newcastle, England. He died on August 30th, 1909, after an unsuccessful operation had been performed, and his body was there buried.

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AWARD OF PRIZES.

These papers will be found in Proceedings for the years indicated.

1903.

JAMES COPPER BAYLES, M. M. E. N. Y., for paper entitled:
The Problem of the Maintenance of Asphalt Pavements in Manhattan.

1904.

GEORGE WILLIAM TILLSON, M. M. E. N. Y., for paper entitled:
The Maintenance and Repairs of Asphalt Pavements.

1905.

SIDNEY WILLETT HOAG, Jr., M. M. E. N. Y., for paper entitled:
The Dock Department and the New York Docks.

1906.

ALFRED DOUGLAS FLINN, M. M. E. N. Y, for paper entitled:
The Organization of an Engineering Force in New York City.

1907.

EDWARD HENRY HOLDEN, M. M. E. N. Y., for paper entitled:
Traverse Work in Connection with the Triangulation of Bronx Borough.

1908.

ROBERT RIDGWAY, M. M. E. N. Y., for paper entitled:
Subsurface Investigations of the Board of Water Supply for the Proposed Catskill and Long Island Aqueducts and Reservoirs, Northern Aqueduct Department.

PAST PRESIDENT MEDALS.

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ROBERT REYNOLDS CROWELL	1909

INFORMATION.

MEETINGS.—Regular meetings are held in the Engineering Societies Building, No. 29 West 39th Street, Manhattan, on the fourth Wednesday of each month at 8:30 P. M., except in June, July and August. The Annual Meeting is held on the fourth Wednesday in January.

LIBRARY.—The Society rooms and library are open every day and evening, including Sundays and holidays. Keys may be obtained from the Secretary on the deposit of 25 cents each.

Members of the Society and all who feel an interest in the maintenance of a technical reference library, devoted more especially to the subject of municipal engineering, are asked to donate engineering books, reports, specifications, maps, plans and photographs.

PROCEEDINGS.—The Society issues one volume of PROCEEDINGS each year, usually in May. It contains all of the papers presented during the preceding year, the annual address of the President, the final reports of special committees on professional subjects, descriptions of the works visited by the Society, and the speeches delivered at the annual banquet, which are of permanent value.

Proceedings are furnished without extra charge to members, and are sold for $2.00 in cloth and $1.50 in paper. Exchanges are desired with other societies, libraries, colleges, etc.

PAPERS.—Papers and discussions on subjects of engineering interest are invited from all persons, whether members of the Society or not. They are, of course, subject to proper editorial supervision. All papers on their acceptance become the property of the Society.

BADGES.—The badge of the Society is of gold with blue enamel in the design shown on the title page of this book. It has a number engraved upon the back, and may be obtained as a pin, a watch charm, or a button. The price is $4.00. Application for it should be made to the Secretary.

CERTIFICATES OF MEMBERSHIP.—The certificate of membership is steel-engraved on parchment paper, engrossed with the name of the member and the date of his election; the seal of the Society is impressed, and it is signed by the President and Secretary. The size is 14 by 18 inches, and the price is $2.00. Application for it should be made to the Secretary.

REMITTANCES.—All remittances should be made payable to the order of Municipal Engineers. They should be made by check on New York or by post-office or express money order payable at New York.

ABBREVIATION FOR MEMBER.—The Board of Directors has authorized the use of the abbreviation "M.M.E.N.Y." to signify "Member of the Municipal Engineers of the City of New York."

INDEX TO PREVIOUS VOLUMES.

PROCEEDINGS FOR 1903.

PROCEEDINGS FOR 1904.

*Prize paper.

PROCEEDINGS FOR 1905.

PROCEEDINGS FOR 1906.

*Prize paper.

PROCEEDINGS FOR 1907.

* Prize paper.

PROCEEDINGS FOR 1908.

*Prize paper, portion by Mr. Robert Ridgway.

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